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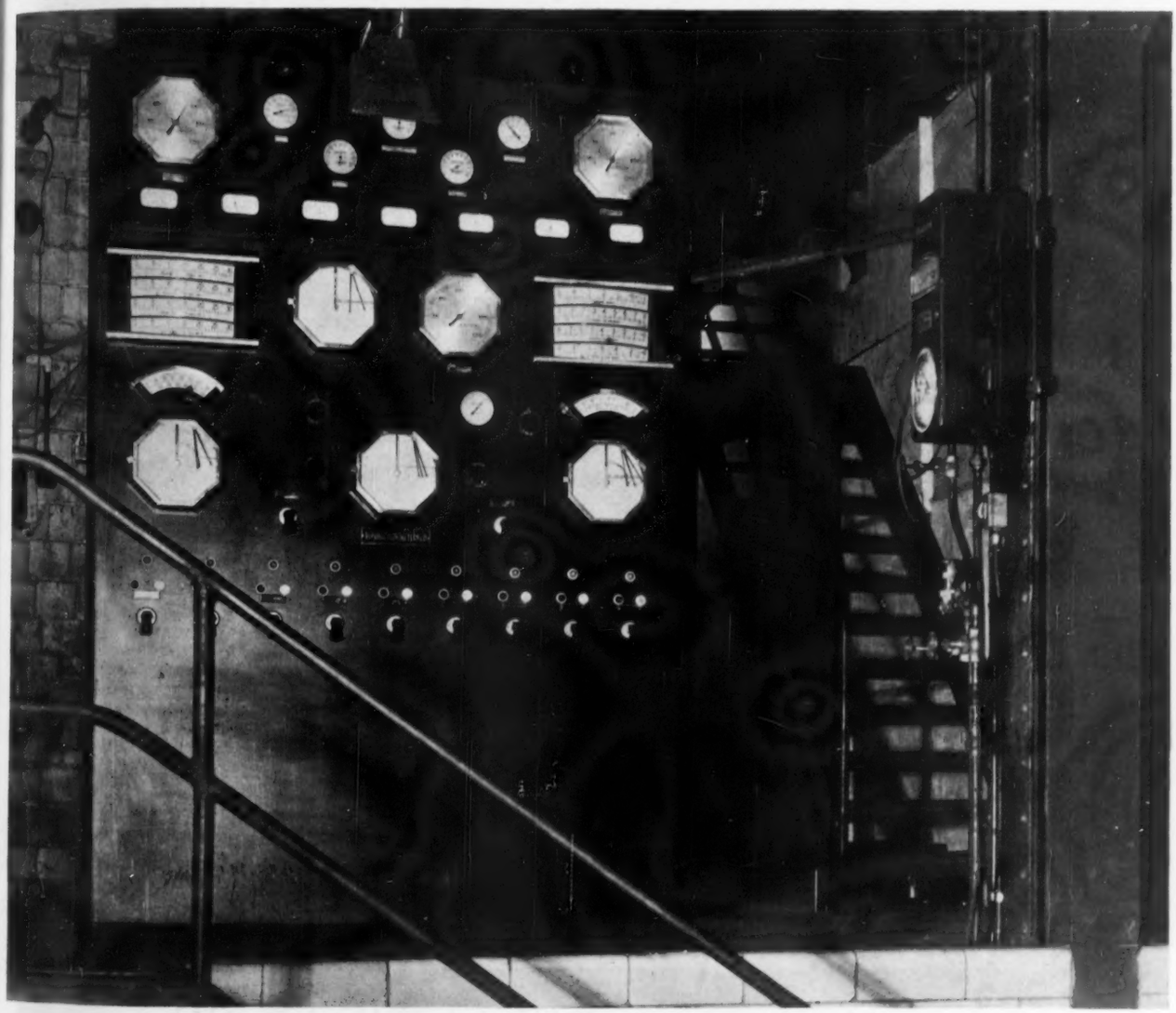
INSTRUMENTS

THE MAGAZINE OF MEASUREMENT AND CONTROL

VOLUME 7 OCTOBER, 1934 NUMBER 10



BOILER PANEL AT GOODYEAR TIRE & RUBBER CO., AKRON, OHIO

See Page A4

(Courtesy Republic Flow Meters Co.)

NRA
WE DO OUR PART

4 QUESTIONS... *and 4 Answers*

WHAT MAKES GREATER POTENTIOMETER ACCURACY POSSIBLE?

A. The following three combined—

1. A slide wire capable of this greater accuracy.
2. A galvanometer sensitive enough to make use of that accuracy.
3. A mechanism that accurately responds to galvanometer movements.

WHY IS THE BROWN 40" SLIDE WIRE MORE ACCURATE?

A. The Brown Slide Wire (several times longer than found in other types of Recording Potentiometer Pyrometers) has more convolutions and has larger diameter wire, wound on a large core. Because of this, each convolution can be selected accurately.

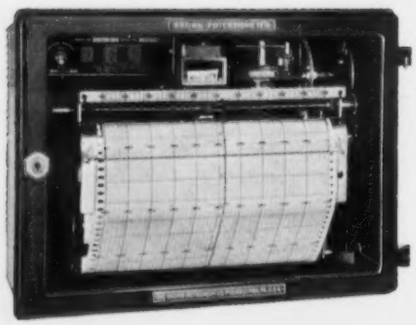
The slide wire is totally enclosed, immersed in oil, protected against corrosion.

HOW IS SENSITIVITY OBTAINED IN THE BROWN GALVANOMETER?

A. Sensitivity is obtained by the use of an extra long pointer which gives greater galvanometer deflections for minute temperature changes. The extra long pointer also permits the use of rugged suspensions. In addition, the galvanometer is enclosed in a separate housing protected against air currents, dirt, dust and fumes that would otherwise affect sensitivity.

HOW DOES THE MECHANISM RESPOND TO THE GALVANOMETER?

A. Minute galvanometer movements are converted into powerful movements of a rugged secondary pointer that controls the positive (pawl type) drive mechanism which eliminates lost motion in recording temperature changes. It can move rapidly in large steps, or take its smallest step of 1/1200th of the chart span with absolute definiteness.



LET'S LOOK AHEAD!

You may think your process does not need extreme accuracy today, but competition in industry is constantly demanding more precise manufacturing methods. Recognizing this trend, progressive industrialists in increasing numbers are repeatedly buying Brown Potentiometer Pyrometers.

Brown Potentiometer Pyrometers have the accuracy, combined with ruggedness, that will be demanded in the future. Why not obtain this advantage today? Write for Catalog No. 1101.

THE BROWN INSTRUMENT COMPANY
4482 WAYNE AVENUE PHILADELPHIA, PA.

Branches in 22 Principal Cities

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BROWN POTENTIOMETER PYROMETER

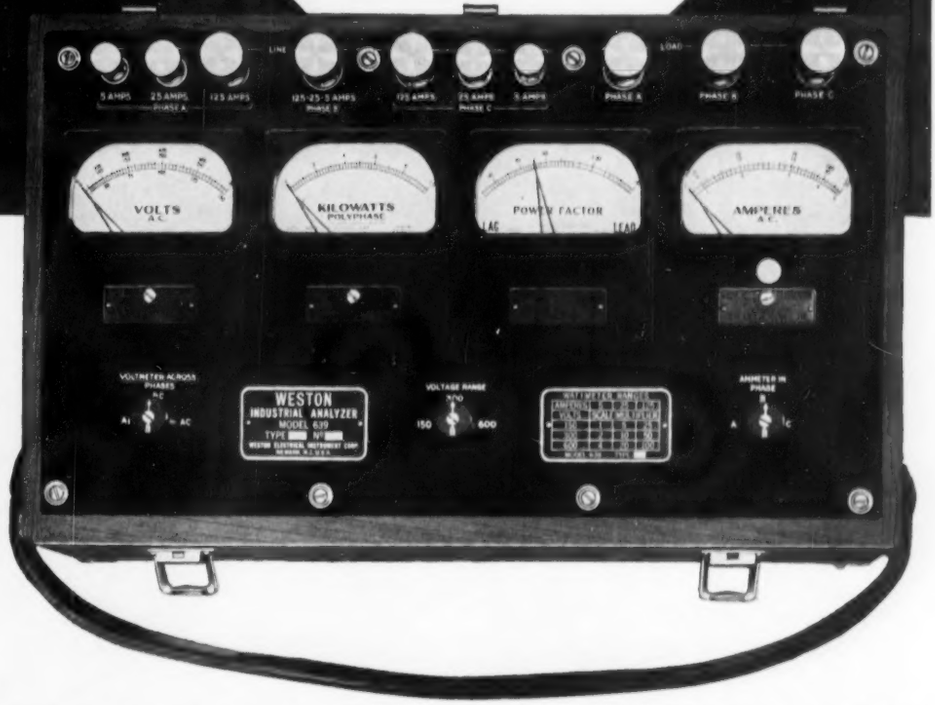
Brings Laboratory Accuracy to Industry

Announcing....

THE

WESTON

INDUSTRIAL POWER ANALYZER



–A SIMPLIFIED, SELF-CONTAINED ANALYZER OF ELECTRICAL LOADS

Mounted in a sturdy, portable carrying case, this new WESTON unit provides for quick and complete analysis of industrial loads. It measures current, voltage and power in single or polyphase circuits and power factor in 3-phase circuits . . . without the necessity of hooking up individual instruments. In addition, provision is made for measuring transients such as starting current of induction motors.

It's the new WESTON Model 639 Industrial Analyzer, which makes load testing quick and simple. Here's an example:

To get full line characteristics of a 3-phase circuit with this analyzer, simply hook on the three line leads and the three load leads . . . just one hook-up. With the selector switch at the left, voltage readings are obtained across any pair of the three lines, and the switch at the right connects the ammeter to read current in any one of the three . . . without in any way interrupting the operation of the circuit. That's all there is to it.

Because of its time-saving features, its simplicity and its positive indications, Model 639 is the ideal tool for plant maintenance and for servicemen and contractors. A bulletin is available with complete data. Send for a copy. Weston Electrical Instrument Corporation, 591 Frelinghuysen Ave., Newark, N. J.

WESTON *Instruments*

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INSTRUMENTS

THE MAGAZINE of MEASUREMENT and CONTROL

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"IF I WERE YOU

I'd look into

TAYLOR TEMPERATURE CONTROL"

"WE HAVE used the Taylor System of Temperature Control in our plant for more than a year and know that its cost has been more than paid for in the savings it brought about."

That's the story many plant owners can tell today regarding *engineered temperature control.* There are plants that, in a year, have secured savings amounting to *more than three times* the cost of equipment and installation of the control system.

Executives of bakeries, oil refineries, textile mills, canning plants, power plants, paper mills, meat packing plants, breweries, and many others can all testify to the value of exact control by Taylor instruments.

Wherever temperature control—or pressure or flow control—is necessary, a Taylor System of indicating, recording and controlling instruments can be engineered to do the work accurately, efficiently and economically.

Ask a Taylor Representative for a survey of your plant to determine how much Temperature Control can do for you. Every Taylor System is a "Taylor-made" system, engineered and installed to fit special needs and conditions. For help on any problem involving temperature, pressure, or flow—address Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada.

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Indicating Recording • Controlling

TEMPERATURE, PRESSURE *and* FLOW INSTRUMENTS

EDITORIAL COMMENT

In This Issue

Every two years or so we depart from our rule on printing only exclusive articles—when one of great interest to our readers appears where few would see it. In *Radiography and Clinical Photography*, published by Eastman Kodak Co., there appeared recently an article of just this kind, and it is with pleasure that we make it this month's leader.

Increasing use of electrical instruments and increasingly critical appreciation of their performance—both largely stimulated by *Instruments*, if we may say so—made it important to correlate different ideas on the factor of merit. R. W. Carson not only does this but adds his own well-matured ideas.

"The potentiometer," declares Dr. C. V. Drysdale, "is the most generally useful of all accurate electrical instruments." To which we need not add a word in referring to the 12-page treatment of manually-balanced d.-c. potentiometers in this month's issue.

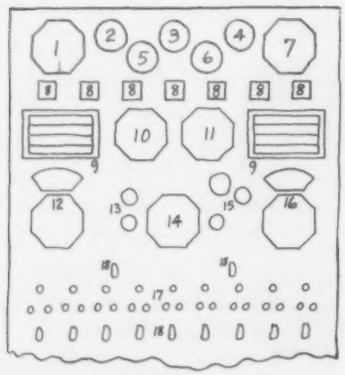
That our Manual instalments are up-to-date has often been demonstrated the last few years. This month, two of the potentiometers described are 1935 models: the diagram of one was drawn *this month* by the makers, the other was *built this month*.

ERRATUM—Equation (5), page 189, last month's issue: for 1.555 read 1.155.

The Front Cover

For the second month in succession we are able to give a detailed list of the instruments on our front cover. The boiler panel was made up for Goodyear by Republic, whose advertising manager, Herb Stoetzel, sent us a blueprint giving the following:

1. Drum pressure gage
2. Air gage
3. Master impulse gage
4. 60-lb. air gage
5. Load gage
6. Fuel gage
7. Superheater outlet pressure gage
8. Seven ammeters
9. Two 4-unit draft gages



10. Coal-air mixture temperature recorder (2-pen)
11. Feed water pressure gage
12. Steam flow indicator and 3-pen steam flow, pressure and temperature recorder
13. Load control relays
14. 3-pen temperature recorder
15. Fuel control relays
16. Feed water level indicator and 3-pen feed water temperature, pressure and level recorder
17. White, red and green bull's eyes—9 each.
18. Eleven switches

Also shown on the photograph is a "Ranarex" CO_2 indicator-recorder made by the Permutit Co.

Instruments Dominate Metal Show

IF on account of distance or for any other reason you missed the 1934 National Metal Exposition now being held in New York, you missed seeing "an Instrumentation museum with metallurgical features and additions." Too bad that by the time this appears in print the exposition will be over. It may not be amiss, however, to make this month's editorial comment a tribute to the recent advance of Instrumentation in the fields of production, fabrication, treatment and application of metals and alloys, by setting down without flowery adornment some of the back-of-envelope jottings we made hastily this afternoon. Here they are, in alphabetical order:

Baldwin-Southwark. Demonstrating Emery machine with new Selsyn-driven recorder; featherweight scratch extensometer; Huggenberg tensometer; proving instruments; Carpenter torsion-impact tester; R. R. Moore fatigue tester in operation; Emmons static torsion tester.

Bausch & Lomb. Microscopic and spectrographic equipment from small & simple to most elaborate & latest; measuring microscopes for shop & lab.; large quartz spectrograph with accessories for quantitative results; large metallographic equipment set up in front.

Bristol. One of largest booths. Extensive line including new: transmitter for Metameter, "B-Linator" (pronounced bee-line-ator) anti-hunting control device, resistance thermometer, elec. recorder-controller with mercury switch, inverted penarm recording voltmeter in rectangular case.

Brown. Millivoltmeter and potentiometer types of indicating, recording and control pyrometers in operation. Educational exhibits of cut-away instruments & of flowmeter bodies. Interesting to compare electrical & mechanical head meters & area meter.

Ferrous Magnetic. Demonstrating production inspection equipment and abnormality detector; exhibiting wire & strip analyzer and magnetic furnace-control unit.

Foxboro. Demonstrating elec. furnace arranged for creating exaggerated conditions of lag, equivalent to ±30°, brought down to straight-line control by "De-Oscillator" while you watch. Also "Rotax" controller, edgewise elec. instruments and extensive line of temperature, pressure and flow instruments.

General Electric X-Ray. Demonstrating new method of radiographing welded seams up to 4" thick.

Gogan. Demonstrating bench and floor Brinell testers.

Hauck. New "micro-regulating" fuel-oil control valve.

Illinois Testing Labs. Self-contained and remote-reading pyrometers.

Kelley-Koett. Various X-ray inspection equipments, one operating.

Leeds & Northrup. Demonstrating: new "Thermotube" recorder-controller which controls from metal temperature, not from furnace atm. temp.; Vapo-Carb; Homo; new Micromax combining numerals & colors.

Leitz. Metallographic equip'ts with improved illum. & optical systems featuring darkfield & polarized light. New vacuum heating stage and univ. photogr. equip't, both rec'd in U.S. 2 days before exhib. opened.

Magnaflux Corp. Prof. deForest demonstrated his magnetic method and special powder for detecting defects; also equip't for magnetizing materials.

Magnetic Analysis Corp. Demonstr. portable equip't for detecting mech. defects, materials of foreign analysis and struct. changes in bar stock. etc.

Minneapolis-Honeywell. One of largest booths. Numerous improved models. Featuring proportional system of auto. control, Protectoglow system of combustion safeguard, Modutrol system for air-conditioning.

Olsen. Demonstr. 20,000-lb. univ. testing mach. with 8-speed drive & pendulum weighing system; univ. impact tester; spring testers; provers; strain gages, etc.

Partlow. So many new temp. controllers & safety gas valves that our N.I. Section may have to be expanded if Al. sends 'em all in.

Pyrometer Instr. Co. Featured new triple-range optical type for steel mill, lab. & foundry.

Scherr. Zeiss optical measuring instr's and stroboscope; Parkson gear testers.

Selas. Auto. gas-air proportioning control in operation.

Shore. Scleroscopes, Durometers, Monotrons, etc. New small internal-testing Monotron.

Tagliabue. Demonstr. potentiometric recorder-controller of "proportional non-drifting non-hunting" type with 0-1600°F. scale holding a small furnace to ±1°F.; also just-completed indicating potentiometer with mirror galvanometer and a new 2- or 3-position indic. pot'r controller.

Testing Machines, Inc. Demonstr. compl. line of Schopper testers: tensile, hardness, impact, abrasion, torsion, bending & folding.

Wilson Mech. Instr. Co. Demonstr. Rockwell line & Suvant (formerly Smith-Taber) stiffness testers modified for testing metals.

Zeiss. Demonstr. micrographic equip'ts & various microscopes, illuminators, etc.

M. F. BEHAR

X-RAYS IN INSPECTION

By E. W. KOLB*

X-RAYS in industry, as in the hospital, safeguard human life. There is this distinction: In the hospital, x-rays are used to determine the location and extent of damage already done; while in industry they are used to examine materials both before and after processing to avoid disaster to multitudes of people. Imagine the calamity that would follow the bursting of Boulder Dam, for example. In order to prevent it, x-ray film is being used by the mile. Every inch of the 80 miles of welded seams of the 13,000 feet (55,000 tons) of steel pipe, 8½ to 30 feet in diameter and 2⅞" thick, and many other parts of this structure, are being radiographed to safeguard human life. Or can you imagine the holocaust that would follow the explosion of a high-pressure boiler located in the densest section of a large city? While the seams of such boilers are welded for safety, it is common practice to radiograph them before installation.

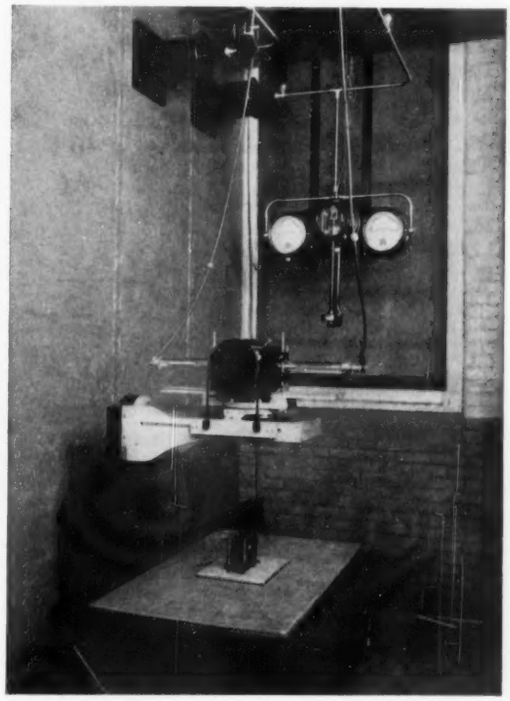


Fig. 1. Exposure room of Radiographic Department of the General Railway Signal Co.

Railway signalling is designed and installed primarily to protect human life and secondarily to expedite the movement of trains. Some time when your train is stopped for no apparent reason, your impatience may be somewhat assuaged if you remember that railway signalling has stopped you a mile or so short of an accident, perhaps a mile or two short of eternity. If signalling fails to perform its proper function, it is worse than no signalling, for in its absence other, though less effective, means would be provided to safeguard human lives. All man-made things fail. Railway signalling is so designed that if failure occurs, it must be on the side of safety—that is, a train may be stopped or delayed by a failure. One such failure may occur once in a million operations of a railway signal device, yet these devices must be so manufactured, installed, and maintained that a failure will not cause a dangerous condition. Hence, the necessity for utmost care in the selection of materials and in the processing, assembling, and inspection of these materials.

Inspection of signalling material includes x-ray examination of certain important parts, such as the silver-impregnated carbon contacts which are used in relays or other devices for opening and closing electric circuits. Whenever a circuit is opened at one of these contacts, a tiny arc is formed tending to fuse the contact. During an electrical storm, when static charges are induced in the signal wires, the arc may be quite appreciable. These contacts must be nonfusible; hence, carbon is used for the basic material. They must be of low electrical resistance; hence, molten silver is forced into the minute pores of the carbon structure. The proportion of silver and carbon must be quite exact and the silver must be evenly distributed throughout the carbon. There must *not* be any continuous thread of solid silver extending through the carbon as this might fuse to the other member and cause a dangerous failure. These contacts are purchased in large quantities and *every* such contact is x-rayed (about 1,000 pieces on a 14" x 17" film). The radiographs are carefully inspected. A few characteristic samples, rich and poor in silver, are also selected for chemical analysis to determine the proportion of carbon and silver. All contacts on any radiograph that are obviously satisfactory are sent to stock for use. All that are in any way questionable are set aside and when the lot is finished, they are again x-rayed in two positions on the same film. This second radiographic record is very carefully examined under a magnifying glass, the defective contacts are destroyed and good ones sent to stock for use as and when required, with the certain knowledge that all in stock are suited to function as intended.

While our x-ray apparatus was purchased primarily for the examination of these contacts, it was soon found valuable for other purposes; *e.g.*, gray iron, malleable iron, and steel castings; butt (pressure) welds, flame welds, and arc welds; molded Bakelite parts having metal inserts or suspected of containing metal inclusions; apparatus assembled in metal or other opaque cases where the relative position of parts cannot be seen after assembly.

There is no such thing as a perfect material or a faultless workman; hence, an inspection department. It is only possible to accept such material as is amply suitable for the purpose intended. A certain allowance or tolerance must always be made and the apparatus designed accordingly. For example, commercial electric motors are so designed and made that they will carry a 10% overload continuously or a 50% or perhaps 100% overload for a certain short time, without damage to the machine. All things requiring strength are built with a factor of safety. A bridge with a factor of safety of 5 will carry a load 5 times as great as it is ever expected to carry. These things are fundamental. Every metal casting is expected to (and does) have some gas pockets, sand inclusions, shrinkages, etc. All lumber has some

*Mgr. Commercial Tests & Inspection, General Railway Signal Co., Rochester, N. Y.

knots, season cracks, shake, wane, etc. The only question is how much of any or all of these defects can be allowed. In every casting there are some parts where defects must not occur and other parts where it is amply strong (made so for other reasons) and therefore can stand quite large defects without detriment to the purpose intended. By changing the foundry technique defects can be either eliminated or made to occur only where they will do no harm. Perhaps they can be driven into the risers or gates, for such parts are cut off before the castings are used.

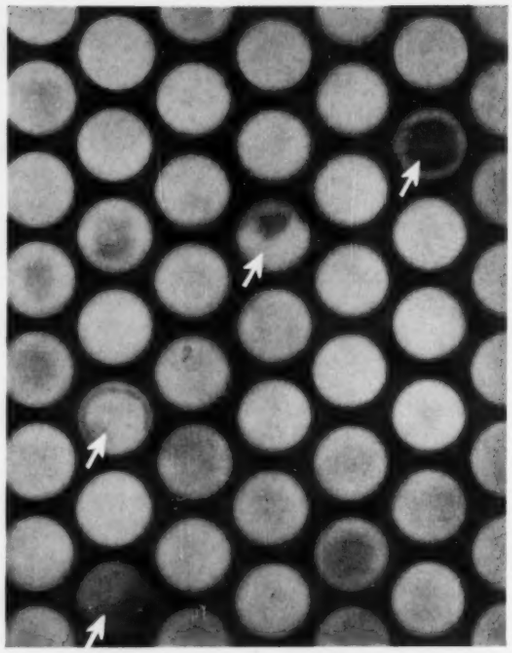


Fig. 2. Actual-size section of a 14" x 17" radiograph of silver-impregnated carbon contacts. Note a few of the defective contacts indicated by arrows.

It is not commercially practical, necessary, or advisable to x-ray all castings. It is well known that if a correct foundry technique is once established and maintained, suitable castings will be produced. When difficulty is experienced in making a suitable casting from any pattern, sample castings are x-rayed. It is always found that the defects are similar in all samples. The foundry technique is then changed and more samples x-rayed. This is continued until suitable castings are obtained and the new foundry technique established. Thereafter, occasional castings are taken from production and x-rayed to see that the practice continues to bring satisfactory results.

An example of this procedure is shown in the radiograph of a gear blank (Fig. 3, left) in which flaws occurred in the rim of the wheel where the gear teeth are cut and were of such a nature that the teeth were abnormally weakened. The first samples showed the faults in the same location on each of five. A special melt of metal produced five superior samples. A third lot of samples made from standard metal to which had been added in the ladle a small amount of another metal, produced entirely satisfactory castings (Fig. 3, right), almost as good as the second lot. It obviously is out of the question to melt tons of special metal to make a few pounds of gear blanks, but quite practical and simple to use the last method where a small part of any run of cast iron could be used to make a few small gear blanks by alloying it in the ladle. This procedure generally followed has enabled us to produce superior castings at only a very slight increase in the manufacturing cost.

Arc and acetylene welded seams, while of utmost importance, have too often been described in published articles to need further attention here. Another form of weld, known as butt or pressure weld, has not been so often described. A certain type of rod—a most important part—if made of one piece was very expensive to manufacture, but if it could be made of two pieces of different size rod welded together, it could be made at much less cost and would, we thought, be quite as strong as when made of one piece. We made a lot and x-rayed them, changed our forging technique a few times, x-raying successive steps, and finally our presentation of the radiographic proof (Fig. 4) was rewarded by the pleasure of our customer.

Bakelite insulation into which are molded metal parts provides a fertile field for x-ray examination. Bakelite before molding is a fine powder made of finely ground vegetable fibre and synthetic resins. Under the influence of heat and pressure it is transformed first into a semi-liquid and then into an inert solid. It is, therefore, easily penetrated by the rays so that the metal parts stand out

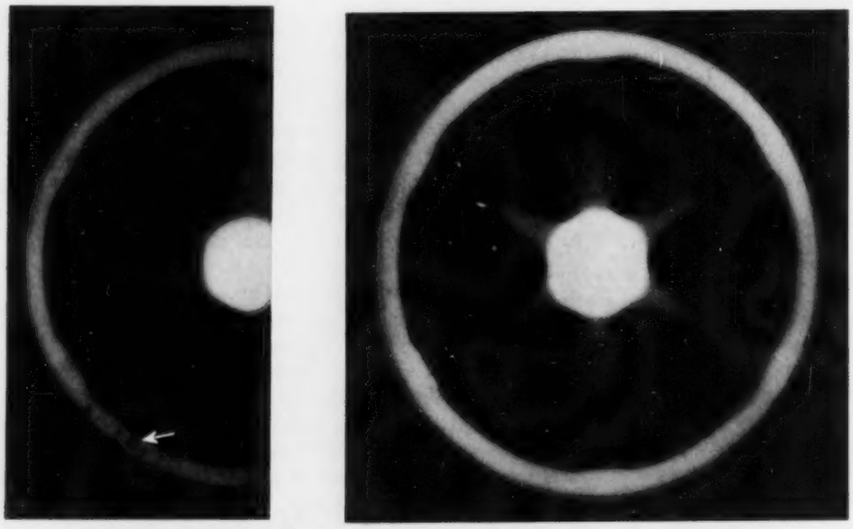


Fig. 3. Radiographs of gear blanks, about ⅜ size. LEFT—Original type of casting showing gas pockets. RIGHT—Casting of lot wherein foundry technique was corrected to produce a better product.

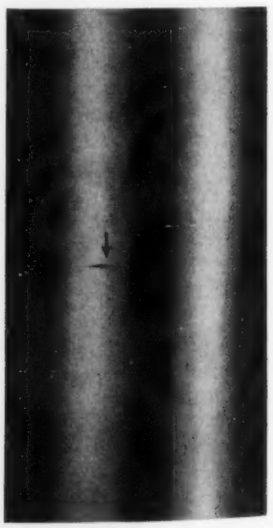


Fig. 4. Radiograph of butt welds, about ½ size. LEFT—Bad. RIGHT—Perfect.

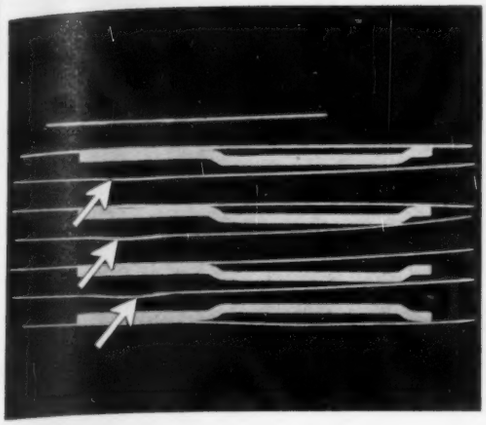


Fig. 5. Radiographs of molded Bakelite with metal inserts, about 4/5 size. Note the distorted inserts indicated by arrows. A correction in molding technique eliminated the distortion.

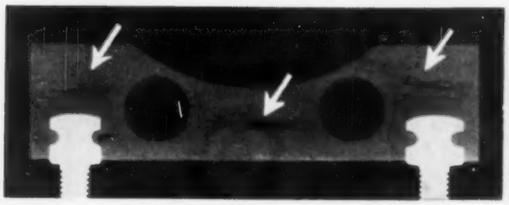
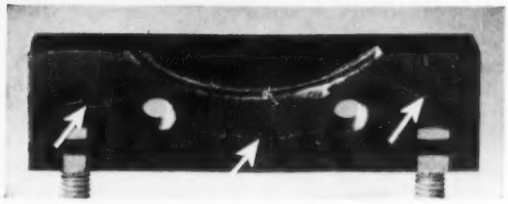


Fig. 6. TOP—Radiograph (about 2/3 size) of molded Bakelite block with inserts. Note porous regions due to improper curing which destroys insulating value.

BOTTOM — Photograph of same specimen sectioned to show porosities revealed in radiograph.



in sharp relief in the radiograph. In the Bakelite blocks shown in Fig. 5, the metal parts are held rigidly in the mold outside the Bakelite but, when the Bakelite starts to flow, pressure tends to move or to distort the metal parts in the mold. If heat and pressure are applied in the correct manner, no distortion occurs. It is to determine this method that such parts are x-rayed when first molded and periodically thereafter to have definite evidence that the established routine is proving continuously satisfactory.

Many mechanisms are assembled and permanently housed in metal cases. It sometimes is advisable to determine the actual relative positions of the parts in a closed case (Fig. 7). This can often be shown quite clearly by x-rays, especially if stereoradiographs are made.

Wound wire resistance units (Fig. 8) are sometimes permanently molded in ceramic or other opaque materials. X-rays make possible the easy and accurate inspection of such parts. Manufacturers of electronic devices similar to those used in radio receivers seem to have a penchant for making the glass enclosing tubes opaque by various methods. In planning new designs or seeking new sources of supply it often is desirable to know the exact relative location of their hidden parts without destruction of the device. This is easily and accurately accomplished by x-ray examination.

Industrial radiography does not always require the same delicate or artistic touch, perhaps, as medical radiography, yet the same principles apply. We all "shoot" for the parts we want to see. The radiologist uses a different technique for bony structure than for soft tissues in the same part, *e.g.*, for the ribs and for the lungs. We have the same problem with metallic inserts in molded Bakelite. We may want to determine the location or condition of the metal parts or to know whether the Bakelite is properly cured in the mold.

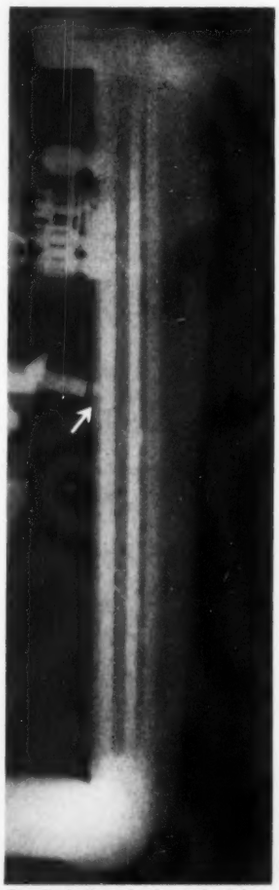


Fig. 7. Radiograph (¼ size) of door of metal mechanism case; one of latches, too long, prevents proper closing.

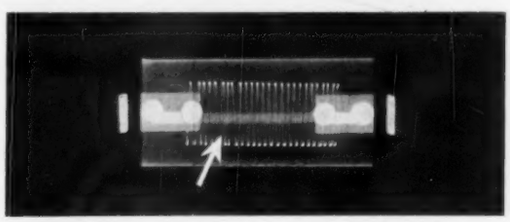


Fig. 8. Radiograph (2/3 size) of enclosed wire wound resistance unit with porcelain core. Unit is enclosed in a metal sheath. Arrow indicates poor spacing of wires which alters resistance value.

If it is not sufficiently cured, it will contain porous spots (Fig. 6) that absorb moisture and change it from an insulator to a conductor of electricity.

The radiologist must consider mobility, dosage, and the comfort of the patient. We may have to consider an idle section of the shop, and men out of work, or a delayed shipment of important material. The radiologist must produce a beautiful radiograph to suit the requirements of an overwrought surgeon. We must tell whether the material is suitable for the purpose intended and prove it by the radiograph.

The *current* used in any exposure is usually limited by the capacity of the tube and the length of exposures. At 5 milliamperes the target of our "deep therapy" tube runs at white heat on all but the lighter exposures. Distances are determined in the same way and for the same reasons as in medical radiography. We usually use 30″ for 8″ x 10″ films and 42″ for 14″ x 17″ films for solid material and 72″ for stereoscopic views and thick, easily penetrated objects. The radiologist's *voltages* run from 35 to perhaps 100 Kv.P., ours from 50 to 200 Kv.P. or higher if the work requires it and if we can afford the more expensive outfit (300 Kv.P. seems to be the present practical limit).

The main difference in technique comes in the *time factor*. Whereas the radiologist may use from 1/20th to 5 seconds, some of our exposures may in extreme cases run 45 minutes or even longer. Most exposures on metals are arbitrarily set at 5 minutes, 5 milliamperes, and 30″, with the voltage as low as possible to get through the material. There is a greater variation in the density or penetrability of materials of the "patient" in industrial work than in the case of human beings. In medical radiography the extremes are bones and soft tissues. Our gamut runs from soft wood to rolled bars or plates of steel

alloyed with tungsten, chromium or other semi-rare metals.

The difference in technique between these extremes is very great. We must consider many metals of different density and thickness. Defects no greater than 2% of the thickness, as required by United States Government specifications for boiler plate, can be shown. We also have materials of the same or different densities and of much different thickness in the same exposure. For example, we had one iron casting (Fig. 9) slightly larger than a 14″ x 17″ film, having grooves and ribs ½″ deep running across the plate in both directions on both sides of the plate so that there were five different thicknesses, ½″, 1″, 1½″, 2, and 2⅛″. We finally showed this all in one exposure by immersing the casting in a solution which was slightly more radioparent than the casting.

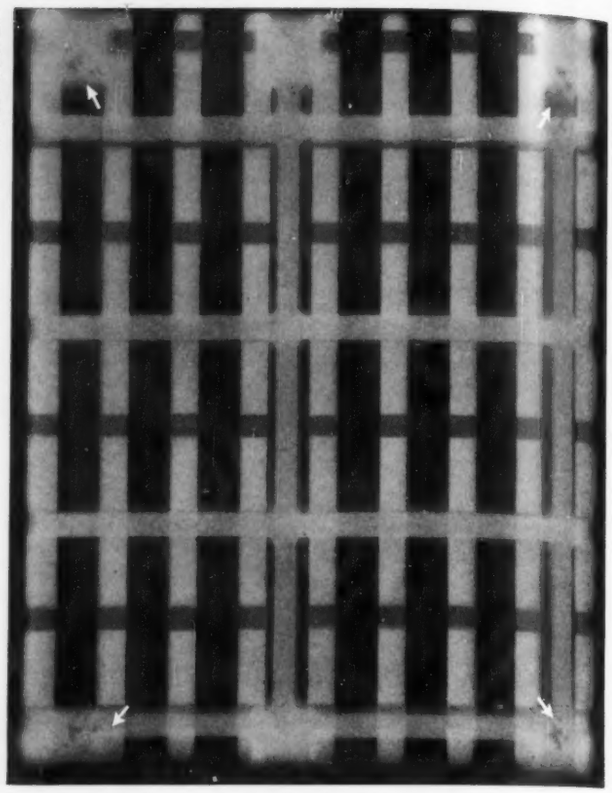


Fig. 9. Radiograph (¼ size) of a casting having ½″ grooves on one side, ½″ ribs on the other, and bosses 2⅛″ thick on the corners. Note uniform density of the radiograph, and defects at corners of casting as indicated by arrows.

Another job (this word is used advisedly) requiring nearly two hundred exposures on 6″ x 17″ films was that of cast steel beams weighing 350 lbs. each. In service these beams were repeatedly subjected to severe and frequent shocks, and were breaking after only short usage. The breaks occurred at four separate points on each beam. X-ray examination of similar beams in stock showed hidden shrinkage cracks at one or more of the four points on all beams. A complete new set of beams was ordered and all of them x-rayed. Each radiograph was numbered consecutively and a corresponding number stamped on the beam. When the radiographs were finished, the defects were plainly marked on each film. Then, each was laid on the corresponding beam, and the location and extent of the hidden crack marked on the beam. An oxyacetylene cutting torch was then used to cut a wide kerf through the hidden crack longitudinally—to literally cut out the defect—and relieve the cooling strains in the remaining metal. A welding torch was next employed to fill in this kerf. When a number of these welds were again x-rayed the radiographs showed the material in the welds to be quite as good as the surrounding metal. These beams have been in service for a year and a half and no complaints have been heard about them. This was a rather expensive job but not nearly so costly as the loss of a valued customer.

LETTERS TO THE EDITOR

But Chains aren't "Framed," Mr. Keith: Most are "Forged" and even "Welded"

To the Editor:

You certainly have been running good material lately. I particularly liked the articles by Sundt and Fett in the August issue and by Bullowa in the current issue. Your own editorials lately have been good but a year ago you ran some rather caustic criticisms of the Administration. Now, in your Sept. editorial, you reiterate not only some of your excellent old statements but also some of your knocks. I agree of course with the paragraph quoting your Aug. 1933 protest against firing research workers from the Bureau of Standards. I am somewhat dubious about the paragraph following, reprinting your Sept. 1933 attack.

In a broad way, I believe that such agencies as the NRA and the AAA have been quite successful in hitting at the root of serious social problems; and although I readily admit that these agencies are not as well run as they might; at least I believe that the AAA has saved us from a Civil War.

This last statement may seem surprising to some, but I happen to have gone through three different South American revolutions and I believe I know how bad things must get in order that some people may start throwing bombs at others.

I also disagree with your implied criticism of the present Government experiments along the lines of electric rates. Of course, we could not have "free electricity, free gas, free rides," but I am afraid that in the case of the electric utilities, most of the trouble is due to the fact that in the past their administrative policies have been dominated by *lawyers*; and that the emphasis has not been on technical improvement and on rendering better and cheaper service; but rather on building complex chains of holding companies and unloading the resulting stock to the public.

These legalistic devices are ingenious, but their value in terms of service is not only zero, but negative. I believe that—without unduly stressing our imaginations—most of us engineers could visualize what might be achieved in terms of human comfort and happiness if the tremendous ingenuity that has gone into the framing of holding company chains had been used instead in the noble task of rendering a real public service.

Ithaca, N. Y., RAFAEL W. KEITH
Sept. 22, 1934 *Research Consultant*

Brief Bouquets for B & B—

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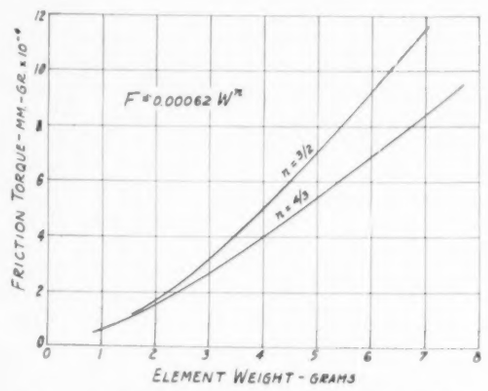
Pacific Gas and Electric Co. OTTO A. KNOPP, *Chief*
Emeryville, Calif. *Bureau of Tests & Inspections*

Merit Factor for Measuring Serviceability of Electrical Indicating Instruments

By R. W. CARSON*

WITH so many intangible factors involved, the measurement of relative performance in modern electrical instruments is a difficult problem. The first requirement, of course, is accuracy in calibration, and fairly well established standards prevail for various types of instruments such as laboratory standards, portables, and switchboard instruments. Temperature errors, scale errors and unbalance likewise are well standardized and readily measured. But for determining serviceability no such standardized methods or design criteria are available.

Serviceability depends largely upon the ability of the instrument to give indications that are free from friction errors. As stated by Brooks[1], "while initial accuracy is important, sustained accuracy is what counts in the long run." For practical purposes this means that friction effects in service must be so small that friction does not influence readings. It thus is apparent that the maximum permissible friction torque depends upon the manner in which the instrument is read, the character of the scale, and the pointer length as well.



For exponents of both 4/3 and 3/2 calculated friction torque differs but little for light-weight elements.

In reading switchboard instruments (having an accuracy of 2%) friction effects as high as 0.25% of full scale introduce no error because of the width of the spade target and the small number of scale divisions. However, instrument users are accustomed to much smaller friction effects, so that a friction torque producing less than 0.1% of full-scale deflection is expected even in switchboard instruments. In portable instruments (read with much greater care and precision) much less friction is tolerable. Since it is desirable to keep friction so small as to be unobservable in ordinary use, friction effects must be equivalent to less than 0.01 in. pointer deflection. Obviously, with a long pointer, the friction torque corresponding to 0.01 in. deflection must be smaller than for the same instrument with a short pointer. Similarly, longer scales call for a smaller permissible friction torque or higher spring torque to keep friction effects unobservable. Finally, for laboratory standards with vernier-type scales that can be read with greater precision, limits for permissible friction are still lower.

Maximum allowable friction torque as a serviceability factor in electrical instruments must therefore take into consideration the minimum observable pointer deflection and the scale length.

It has long been recognized that pivot friction bears a definite relation to movement weight. Nearly thirty years ago Janus[2] suggested that the ratio of torque in millimeter grams to the weight in grams should not be less than 1.7. MacGahan[3] considered 1.5 to be the minimum value for switchboard instruments 23 years ago. Edgcumbe[4] in his first edition (1908) did not mention torque-weight ratios, but in his second edition (1918) differentiated between classes of instruments, giving values of 0.5 for portable instruments and 1.0 for switchboard instruments. At this time, torque-weight ratios were thought to be comparatively simple for Edgcumbe states that "the minimum satisfactory torque depends, other things being equal, upon the weight."

Brooks[5] was the first writer to observe that the ratio should vary with the weight: "As the weight on the pivots is reduced, the value of the torque-weight ratio may be lower for a given frictional error." Keinath[6] a year later suggested that the weight factor in this ratio should be raised to a power greater than 1 but less than 2, a power of 1.5 being approximately correct. Two years later, Brooks[7] pointed out that the simple ratio between torque and weight fails because "the use of the simple ratio is based on the incorrect assumption that the area of the pivot in contact with the jewel is independent of the weight, whereas it must necessarily increase with the weight." Then Fichter[8] reached the conclusion that the exponent should be 4/3 rather than Keinath's 1.5 value.

More recent articles on this torque-weight ratio have presented analytical methods of arriving at the weight exponent, taking into consideration the elastic deformation of the pivot. Lenehan and MacGahan[9] in 1929 presented an equation for friction torque with an exponent of 4/3, assuming that the entire elastic deformation occurred in the pivot. These authors likewise show that for horizontal pivots the radius of the pivot has little effect on the mean friction radius, and that the exponent of the weight is unity. Stott[10] presented a mathematical analysis of the effect of pivot deformation on friction torque. For purely elastic deformation with contact pressure a maximum at the center of contact, uniformly falling to zero at the edge, he also arrives at an exponent of 4/3, assuming that all the deformation occurs in the steel pivot. Stott's work goes still further: in evaluating the maximum load that a pivot of a given radius will support without permanent deformation, and in obtaining a relation for pivot friction that apparently checks well in practice.

As demonstrated by Stott, only the weight of a moving element influences the amount of friction when the minimum safe pivot radius is selected for each instrument. Thus, for a given vertical-pivot element, there is a minimum friction torque that can be obtained without permanent deformation of the pivot. However, most instruments must be designed for use under conditions of vibration or accidental overload, and it is recognized

*Asst. Editor, *Product Engineering*, New York.

that this minimum friction can only be approached in practice.

In a recent article Goss[11] holds that flattening of the end of a vertical pivot is likely to occur either through vibration or wear, the exponent of the weight becoming 3/2. Edgcumbe and Ockenden[12] also state that an exponent of 3/2 is confirmed by experience. However, the practical difference in the calculated friction using the two exponents is small for vertical elements weighing from 1 to 5 grams, as shown in the accompanying curve.

Because of the difference between their torque-weight relations, horizontal-pivot instruments cannot be compared with vertical pivot types on the basis of weight alone. No correlation can be made between the two types without considering pivot radius, flank angle, jewel contour and end play as well as element weight. For vertical-pivot instruments, however, friction depends only on element weight if the smallest practical pivot radius is used in the design of the instrument, assuming that all the load is carried by one jewel. Under these conditions the pivot friction F in millimeter-grams torque in terms of the weight W in grams is given by Stott as $F = 0.000062\ W^{4/3}$.

For instruments with pivots of too small a radius Stott shows that the area of contact between pivot and jewel will increase directly with the load. The torque-weight relation then carries the exponent of 3/2 for the weight. If the pivot is flattened by wear or overload, then for subsequent use the radius of contact remains constant, and the weight exponent is 1.

Thus there are three possible relations between the friction torque and element weight, depending only on the pivot radius:

(1) For pivots subjected only to elastic deformation the relation is, $F = k\ W^{4/3}$

(2) For increasing loads producing permanent deformation, $F = k\ W^{3/2}$

(3) For pivots having a large area of contact produced by wear or overload, $F = k\ W$

As summarized by Stott, "The recognition of these possibilities renders understandable the conflict of views hitherto existing. The result of practical importance is that when only elastic deformation occurs—and this should be assured in the design of the instrument—the friction increases as the 4/3 power of the load."

Applying the first relation to a portable instrument having an element weighing 4 g., if the minimum pivot radius is used, the friction torque is,

$$F = 0.000062 \times 4^{4/3}$$
$$= 0.0004 \text{ millimeter-grams}$$

If this amount of friction is to produce less than 0.005 in. pointer deflection on a scale 6 in. long, the spring torque for full scale must be more than 1200×0.0004 or 0.48 mm.g. The minimum ratio of spring torque T to the element weight ($T/W^{4/3}$) for this example is 0.48/6.3 or 0.076. If the pointer for this instrument is shortened until the scale is reduced to a length of 4 in., the constant for the torque-weight ratio becomes 0.051, while for a scale length of 8 in. the constant is 0.101, assuming in each instance that friction produces a pointer deflection of 0.005 in.

Or the minimum torque-to-weight ratio may be obtained without reference to element weight. Assume for example that a laboratory standard instrument with a 12-in. scale can be read with an accuracy of 1/20%, and that friction must produce a deflection no greater than 1/3 this amount, or 0.002 in. The spring torque therefore must be 6000 times the friction torque. Using Stott's relation for the friction torque, the full scale spring torque in mm.g. is,

$$T = 0.000062\ W^{4/3} \times 6000 = 0.372\ W^{4/3}$$
$$\text{or } T/W^{4/3} = 0.372$$

But if the scale length of this instrument is decreased by reducing the pointer length, the full scale spring torque can be decreased in the same proportion and the instrument will have the same magnitude of friction effect. Therefore, for a scale one-half as long the minimum ratio of $T/W^{4/3}$ is 0.185.

These constants imply that the pivot friction remains unaltered throughout the life of the instrument. But to operate satisfactorily over long periods of time, an instrument must be designed so that increased friction resulting from pivot wear and accidental flattening still does not prevent accurate readings. Therefore, it is not the actual torque-to-weight ratio but the margin of safety used in the design that is an important indication of relative serviceability or the ability of the instrument to deliver "sustained accuracy." This factor of serviceability can be found for any instrument by comparing its value of $T/W^{4/3}$ with the constants given in the accompanying table. These constants are calculated, as in the examples given above, on the basis of friction torque equal to the given minimum pointer deflection, still assuming that the smallest practical pivot radius is used in the design.

The use of a pivot radius larger than the minimum, although providing additional load carrying capacity, increases the friction torque, thus calling for a larger margin of safety over the constant given in the table. The best compromise between these two divergent requirements is given by Stott. For pivots made of hardened, high-carbon steel, the radius R in inches varies with the square root of the element weight W in grams according to the following relation, $R = 0.0005\sqrt{W}$.

This pivot radius, as explained by Stott, "is the minimum radius for a pivot of hardened Stubbs (1% carbon) steel in order that it may support a given load without suffering permanent deformation." The relation given above assumes that the jewel radius is large compared to the pivot radius, but no correction is needed if the jewel radius is more than 10 to 20 times the pivot radius. Only when the optimum pivot radius is used for a given element weight does the torque-to-weight ratio indicate the effect of pivot friction on the performance of vertical-pivot instruments; and for this reason the torque-to-weight ratio alone cannot be used as a "factor of merit."

Minimum Constants for the Torque-to-Weight Ratio $T = k\ W^{4/3}$

Type of Instrument	Max. pivot friction, pointer deflection	Value of k for scale length of— 4 in.	6 in.	8 in.	12 in.
Laboratory standard (vernier scale)	0.002 in.	.....	0.185	0.252	0.372
Precision portable	0.005 in.	0.051	0.076	0.101	0.152
Portable	0.01 in.	0.025	0.038	0.051	.....
Horizontal switchboard	0.02 in.	.....	0.019	0.025	0.038

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[11]Goss. Mechanical Factor of Merit with Respect to Electrical Instruments. *General Electric Review*, Vol. 36, 1933, pages 188-191.

[12]Edgcumbe & Ockenden. Industrial Electrical Measuring Instruments, Pitman & Sons, 1933, page 44.

Potentiometers*

By PERRY A. BORDEN† and M. F. BEHAR**

1. Electrical Balance

Measurement of current, voltage or power is usually performed by opposing and balancing a proportional *effect* by a conveniently measurable *force*. In most instruments thus far discussed the opposing force was *mechanical*, the reaction of a spring or a weight either (*a*) increasing with deflection of the moving part due to electrical or electromagnetic forces, as in most direct-indicating instruments, or (*b*) subject to adjustment from an external source—as in the Kelvin balance—until the electrical forces are balanced and the moving element returns to a zero or neutral position.

There will now be discussed two important classes of instruments in which the electrical magnitude under measurement is opposed by another electrical magnitude of the same class, and a determination made of the value of the latter. Such instruments have a wide application in industry, and for some purposes possess advantages not shared by the direct-indicating instruments. Devices operating on the principle of electrical balance embody circuits which may be said to fall into one or other of two classes: the *potentiometer* and the *bridge*. Between these basic circuits there can hardly be said to exist a definite line of distinction; but, aside from the essential purposes of the two—the former for measuring potential differences, and the latter for determining resistance values—there is a characteristic difference: The potentiometer circuit includes at least two sources of electromotive force, while seldom more than one source is present in the bridge circuit.

2. The Potentiometer Circuit

While the potentiometer has appeared in many forms and is used for many purposes where the measurement of potential differences may be applied, its circuit is based on the most elementary principle of current flow—Ohm's law—that the drop or gradient of potential along a circuit having resistance and carrying a current is definitely related to the resistance value. If a definite current flow in a circuit of definite resistance there will exist between the terminals of that circuit a definite difference of potential. This holds good not only for a complete circuit, but for any selected portion of the circuit; and, since with a given value of current the potential difference will vary as the resistance between the points of reference, it follows that by determining the relative proportionality of resistance values in elements of the circuit between its terminals, the potentials across those elements will bear to each other and to the total potential difference exactly the same ratios as do the resistance values.

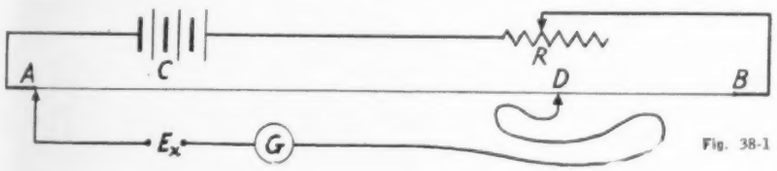

Fig. 38-1

The elementary circuit of a potentiometer is shown in Fig. 38-1, where *AB* represents a *uniform-resistance* wire forming part of a circuit supplied with current from a battery *C*. Now, if the potential across the terminals *AB* be given a definite value, it follows that the potential across any portion of the wire will bear to the total potential the same relation as the length of that portion does to the whole wire. Thus, if the current in the circuit be adjusted by means of *R* till the potential difference between *A* and *B* is 1 volt, and the distance *AD* be ¾ the length of the wire, then the potential difference between *A* and *D* will be 0.75 volt. Since any current drawn from point *D* would tend to disturb the uniformity of flow in the wire, it is necessary that such current be reduced to zero at the time of measurement. Thus, a voltmeter tapped off the potentiometer wire would not give a true indication of voltage conditions

*Tenth chapter (XXXVIII) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Béhar's *Manual of Instrumentation*. See editorial announcement of this series on page A7 of November 1933 *Instruments*. A complete chapter of this new handbook will be published in each issue of *Instruments* throughout 1934 and 1935. Each chapter is subjected to a final revision, and then set in type, shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright. To be issued in book form on or about Jan. 1, 1936.

†Member A.I.E.E. **Editor, *Instruments*

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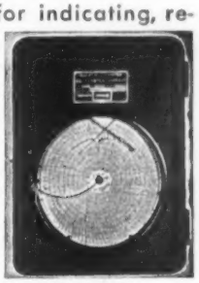

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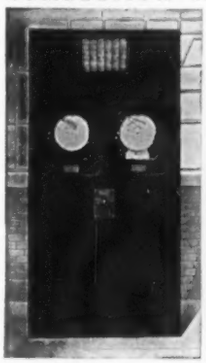

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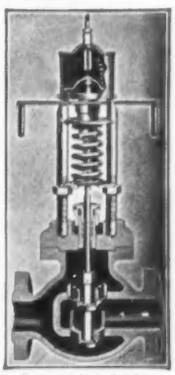

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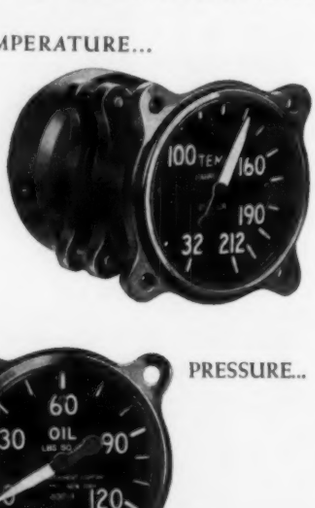
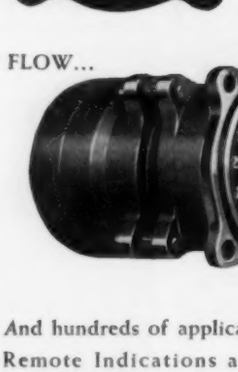
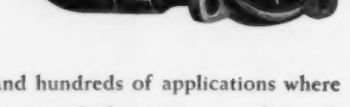




PRESSURE...

FLOW...



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associated with measurement according to the potentiometer principle. In order for the device to function in its true manner it is necessary that the voltage under measurement be balanced against the potential drop along the slide wire, the condition of true balance being detected by a galvanometer introduced between the two sources of potential. Thus, in Fig. 38-1, if E_x represents a voltage to be measured and G a galvanometer in circuit between one side of E_x and a sliding contact D on the wire AB, the other side of E_x being connected to the point A, it is obvious, if D be moved along AB until the galvanometer shows no deflection, that then, and only then, will the potential E_x be equal to that of AD. Under this condition, if the total slide-wire voltage be known, a determination of the voltage E_x rests in a determination of the length of AD relative to that of AB—a linear measurement which may be made with any desired degree of precision.

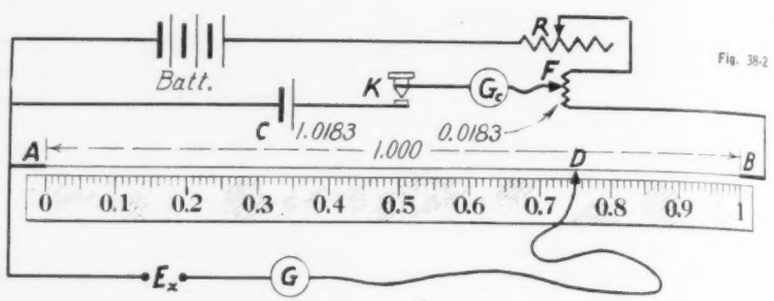

Fig. 38-2

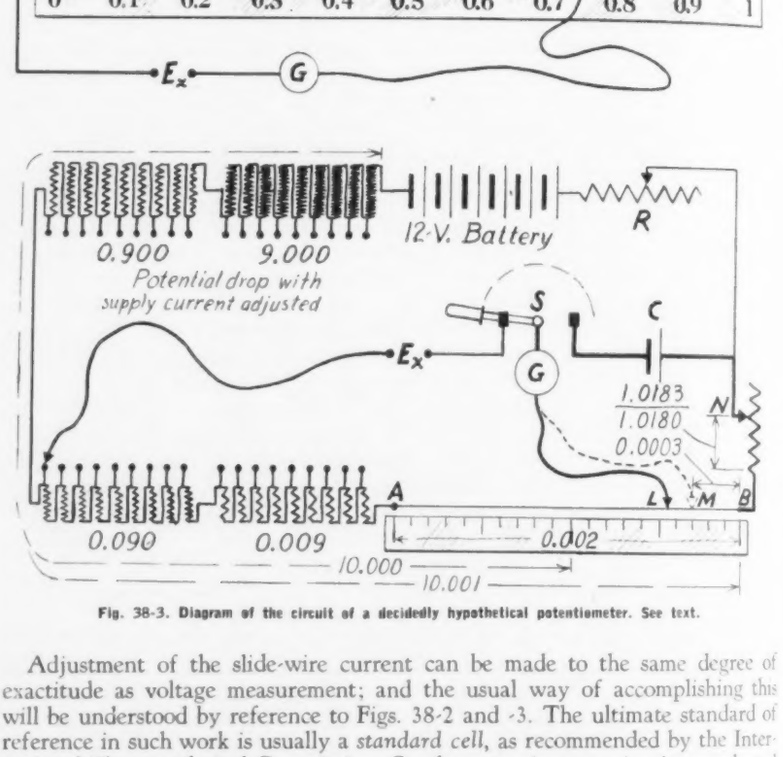

Fig. 38-3. Diagram of the circuit of a decidedly hypothetical potentiometer. See text.

Adjustment of the slide-wire current can be made to the same degree of exactitude as voltage measurement; and the usual way of accomplishing this will be understood by reference to Figs. 38-2 and -3. The ultimate standard of reference in such work is usually a *standard cell*, as recommended by the International Electrotechnical Commission. On the potentiometer circuit are selected two points between which the potential difference with the correct value of current flowing will be equal to that of the standard cell. In Fig. 38-2 one of these points is the terminal A of the slide wire, the other is F; in Fig. 38-3 these points are M and N. The standard-cell voltage is then opposed to that portion of the battery voltage through a galvanometer G_c in a manner similar to that outlined above; and instead of shifting the tap F in Fig. 38-2 (or M or N in Fig. 38-3) to balance the system, the current in the slide wire is adjusted by means of a rheostat R until the galvanometer deflection is reduced to zero, at which time the potential across any portion of the circuit—across the whole wire or across any calibrated division of it—will be known to have the correct value as a standard of comparison.

From the above it will be seen that the accuracy of a (manually balanced) potentiometer is not dependent upon the action of mechanisms, but only upon the adjustment and permanence of resistors; and since the production of resistance materials has reached a high state of refinement and resistance values can be measured to almost any desired degree of precision, the ultimate accuracy depends only upon that of the standard cell. It will be noted, too, that a knowledge of the *actual* values of the resistances in a potentiometer is not

necessary, precision depending only upon the *relative* values of different sections. So, even though the wire forming a potentiometer circuit may have an appreciable temperature coefficient, so long as all parts of the circuit change their values in the same proportion the accuracy of the instrument is not impaired. There is no doubt that of all industrial electrical instruments the potentiometer is intrinsically the most sensitive, the most precise and the most accurate.

In actual instruments various simple switch or key devices make it possible to use a single galvanometer for all balancing purposes. One such arrangement is shown in Fig. 38-3. This is *not* the diagram of an actual make: its main purpose is to show a circuit differing from that of Fig. 38-2 in several respects. For example, the standard-cell circuit has in common with the measuring circuit an extremely small portion: the portion *MB* of the slide wire; and (as implied in the preceding paragraph) these two circuits need not have in common any resistors or slide wires or portions thereof.

The simplest form of potentiometer consists in a single slide wire stretched along a uniformly divided scale, as in Fig. 38-2; and even with such a piece of equipment, readily constructed, and costing but a few cents, potential measurements can be made with surprising precision. In the development of the potentiometer into a complete instrument, the first step lies in the embodiment of the principal part of the resistance in standardized coils, which may be selected by means of a plug or dial-switch system, leaving a relatively small part of the total resistance to be included in the slide-wire proper. In the use of such a form of potentiometer a voltage approximating that to be measured is set up on the dial switch, and the final reading is obtained on the slide wire, which may be subdivided to a high degree of precision. Potentiometers with only one calibrated resistance in the form of a slide wire (Fig. 38-2) are chiefly made up for schools. There is a practical limit in the other direction, too, as will appear from a comparison of Figs. 38-2 and -3. The former represents a potentiometer with a range of one volt, all on a slide wire graduated in hundredths and readable to, say, 2 millivolts. The latter shows a potentiometer with a range of 10.001 volts, with 0.0001-volt graduations, readable to, say, a fiftieth of a millivolt. The degree of precision of the former is lower, that of the latter is somewhat higher, than found in commercial potentiometers. As a matter of fact the combination of calibrated resistors sketched in the latter is as rare in commercial practice as is a ten-inch machinist's micrometer scaled in ten-thousandths and readable to a fifty-thousandth; and this combination, moreover, if made up with inferior quality resistors, would be as much of an absurdity as a machinist's micrometer with a main frame made of lead and a vernier reading to fifty-thousandths.

The slide wire may take any one of a number of forms. It may be straight or may form a single circle associated with a dial-type scale, in which either the slide wire itself may be rotated or a movable contactor caused to slide over its surface. In some cases the slide wire is formed into a helix, and arranged so that the contactor may make several revolutions, its engagement with the proper turn of the helix being assured by a feed screw. In some instruments the wire is helically and closely wound on an insulated wire core, and that core formed into a circle or a helix. Most of these varieties of slide wire arrangements are shown in the specific instruments described in Sections 4 to 7. (*Note.* Only manually balanced potentiometers are dealt with in this chapter; self-balancing instruments in Chapter XL.)

Standard Cells

The foregoing has made it plain that the potentiometer circuit is a *transfer standard*, the calibration of which—in terms of potential differences between given points—depends on adjusting the supply current by the use of a standard cell. No matter what its *degree of precision* may be, the *accuracy* of a potentiometer cannot be better than that of the reference standard which is employed to give it a definite scale. Fortunately, standard cells of adequate constancy are commercially available. These are small galvanic cells carefully constructed with materials of high purity. The cadmium cell invented by Dr. Weston in 1892, in the H form due to Rayleigh, has been developed and refined by various workers until it has become the International Practical Standard for the physical embodiment of the International Volt, the value assigned to the e.m.f. of the "Weston Normal" cell at any temperature T°C. being given by the formula

$$E_T = 1.0183 - 0.000{,}0406\,(T - 20) - 0.000{,}000{,}95\,(T - 20)^2 \ldots$$

which we reproduce without the negligible cubic term. It is important to bear in mind that the reference voltage of a standard cell is always the "open-circuit" voltage, *i.e.*, the potential difference between its terminals at the time no current is flowing in it, so that it is only by a potentiometric method that

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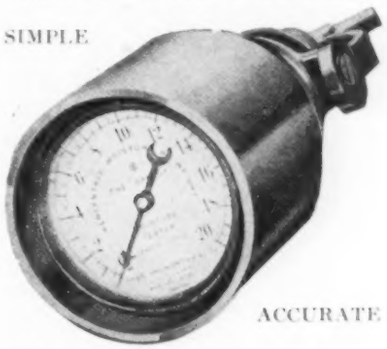

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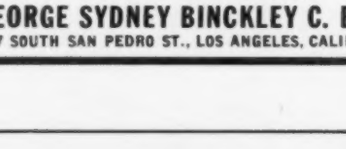

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Fig. 38-4. Weston Elec. Instr. Co.'s standard cell, without case. 1—wax; 2—cork; 3—$CdSO_4$ solution; 4—Hg_2SO_4; 5—mercury; 6, 6—platinum wires; 7—cadmium amalgam; 8—packing; 9—porcelain retainers 10—glass receptacle; 11—cover.

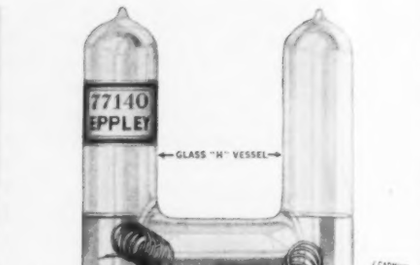


Fig. 38-5. Eppley Laboratory's standard cell, without case.

this voltage may be utilized as a standard (or determined). A voltmeter will not correctly read the open-circuit voltage of a cell; and in no case should a current in excess of a few milliamperes be allowed to flow through the cell. Dr. Eppley's A.I.E.E. paper* may be consulted for details on this subject. The fact that there are in this country two firms supplying standard cells (see Figs. 38-4 and -5) may be the reason why American-made standard cells are superior to the average imported article. The portable "laboratory standard" cells are certified to 0.01%; the (non-portable) "primary standards" are reproducible to five or ten *microvolts*. Portable cells are the ones recommended for industrial work, as they can be sent to the Bureau of Standards every year or two, for certification. For ordinary work at room temperature with a cell that has never been abused, no adjustments or corrections are necessary; for accurate work—to the fourth decimal—it is necessary to adjust precisely the ohmic value of the standard-cell circuit that serves as a base for all the rest, and in actual potentiometers special provisions are made for this purpose.

3. Extending the Range

(a) Potential Dividers

It is apparent that the maximum electromotive force which can be measured by a potentiometer will be less than that of the supply to its working circuit; and in general it may be said that standard types of potentiometers do not have a range in excess of 2 volts, though some of them may be used with applied potentials as high as 20 volts. Where higher voltages are to be measured this is usually accomplished by use of a potential divider or volt-box. This consists of a high resistance suited to be directly connected across the terminals of the circuit to be measured, and having one or more taps taken off at calibrated points between its terminals. With a voltage applied to the volt-box, the potential between the tapped points, so long as no current is drawn, will be in the same ratio to the whole voltage as the resistances of the respective portions of the circuit. With this device, therefore, the range of a potentiometer may be extended indefinitely; and for ordinary voltages (say up to 750) the volt box provides a satisfactory means of range extension. There are on the market numerous makes and forms of volt boxes, including cheap devices never meant to be used in connection with potentiometers. The reliable ones naturally cost several times as much as the inferior ones.

*Eppley. International Standard of Electromotive Force and its Low-temperature-coefficient Form. *Transactions A.I.E.E.*, Vol. 1931.

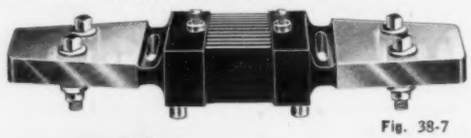


Fig. 38-7

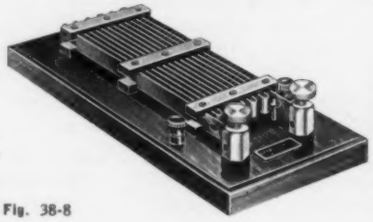


Fig. 38-8

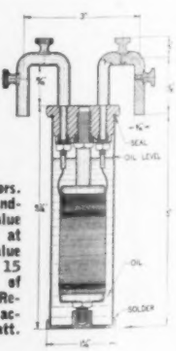


Fig. 38-9

Forms of standard resistors. Fig. 38-7: Heavy-current Standard (⅛ actual size) with a value of 0.000,01 ohm and rated at 3000 amp. Fig. 38-8 has a value of 0.1 ohm and is rated at 15 amp. Fig. 38-9: "Bureau of Standards Pattern" Standard Resistor of 10-ohm value with accuracy of 0.01% <0.1 watt. (Leeds & Northrup)

(b) Standard Resistors

Since the potentiometer is essentially a potential-measuring device, the logical method of using it for current measurement is to employ a standard resistor through which the current to be measured is allowed to flow, the potential drop across this resistor being applied to the measuring circuit of the potentiometer. Standard resistors for this purpose, calibrated to a high degree of accuracy, are obtainable from several makers and in a variety of forms. Where the highest accuracy is required they are arranged for permanent immersion in an oil bath, which accomplishes the double purpose of protecting the resistor material from the atmosphere, and maintaining a uniform and controlled temperature throughout its mass. Figs. 38-7, -8 and -9 show standard resistors of various ohm values manufactured by Leeds & Northrup.

(c) The Divided Circuit

It is apparent that potential differences may be selected at any points along the circuit of a potentiometer, without of necessity making one terminal of the slide wire a reference point. Thus, several potentials may simultaneously be compared with the voltage gradient in the circuit, and these may or may not overlap, so long as a balanced condition exists in each circuit. In some forms of the instrument the circuit is divided into parallel sections, the measuring voltage being taken between points on each. This greatly increases the flexibility of the instrument and also makes possible compensation for potentials which it is not desired to include in the ultimate measurement.

4. Representative Potentiometers

While a great variety of true potentiometer circuits and different forms of instruments have been developed, space will not permit of their detailed treatment, and only brief outlines of some interesting commercial models will be given.

Since there are many and diverse criteria by which potentiometers may be compared with one another, the authors deem it necessary to remark here that *any* well-built null-method potentiometer belongs to the élite of electrical instruments. Most valid criteria pertain to actual construction: (1) uniformity of slide wire; (2) eliminating effects of contact resistance; (3) eliminating thermoelectric effects; (4) mechanical and chemical protection of the slide wire and of all other resistors, etc.

There also are criteria of a more or less controversial nature, with sound arguments advanced both pro and con. Among these we may cite

(1) the presence or absence of sliding contacts in the potentiometer circuit proper;

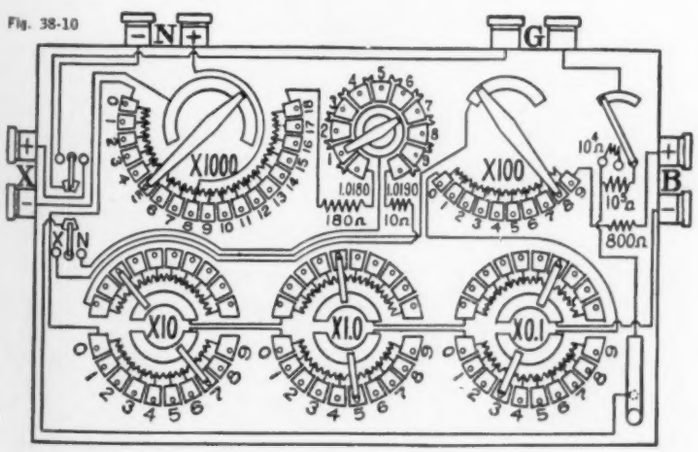
(2) the total number of contacts in the potentiometer circuit proper;

(3) the total resistance of the measuring circuit, which has a bearing on (*a*) galvanometer sensitivity, (*b*) accuracy as affected by leakage currents, (*c*) drain on the main battery, (*d*) constancy of resistance values and hence of ratios, (*e*) first cost, (*f*) maintenance required and (*g*) the possibility of constructing an instrument with decade boxes only and no slide wire.

Without taking sides we shall first present examples of the "high-resistance" class and then of "medium-resistance" and "low-resistance" instruments.

The "high-resistance class" is frequently called the Feussner type because it employs the circuit due to Feussner (1890). Of this type, the oldest example in fairly widespread use in this country is the one made in Berlin by Wolf and sold in the United States by Biddle. Fig. 38-10 shows its arrangement. It is in the 20,000 ohm class.

Fig. 38-10



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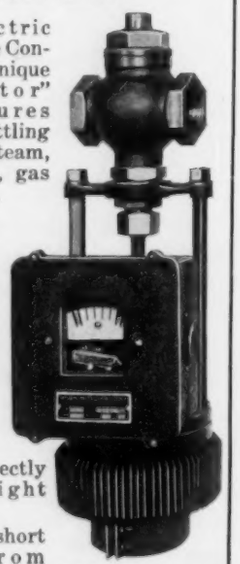

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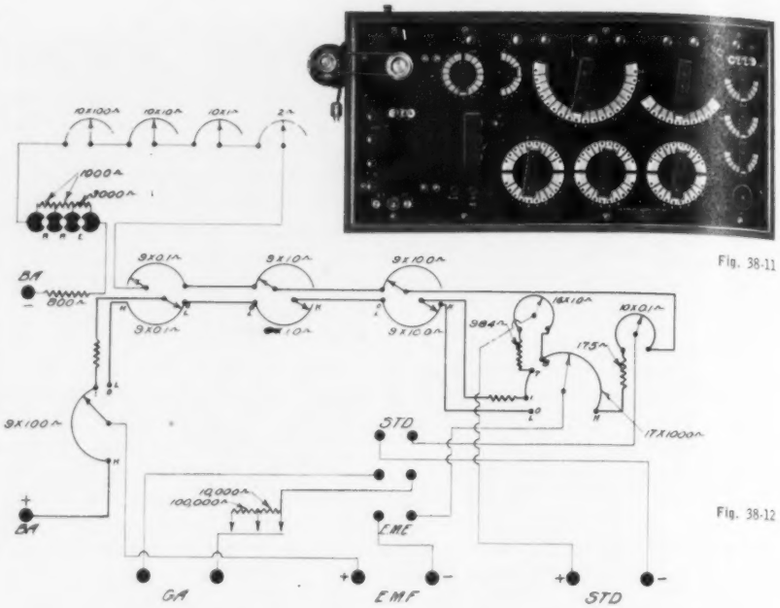

Fig. 38-11

Fig. 38-12

The Eppley Laboratory's "Improved Feussner Type" is a recent modification* of this fundamental circuit, as may be seen by examining Fig. 38-12. Dr. Eppley has eliminated several contacts in the original circuit, added a "standard cell dial" for greater precision in adjusting the standard cell circuit when using standard cells of different voltages and built into the instrument a rheostat for the battery circuit. Note from Fig. 38-11 that the resistors are all immersed in a motor-agitated constant-temperature oil bath.

The Queen-Gray "Model E 3040" (Figs. 38-13 and -14), of the "medium-resistance class" (900 ohms), is distinguished by having a single-turn slide wire —made possible by the use of a divided circuit—mounted within the instrument case which is practically air-tight—an obvious advantage in most industrial plants.

While the General Electric "Precision Type Potentiometer," Figs. 38-15 and -16, is of the "low resistance class," the slide wire is eliminated by the

*M. Eppley and W. R. Gray. An Improved Feussner Type Potentiometer. *The Review of Scientific Instruments*, Vol. 2, April 1931, pages 242-249. For abstract see *Instruments*, Vol. 5, April 1932, page A12.

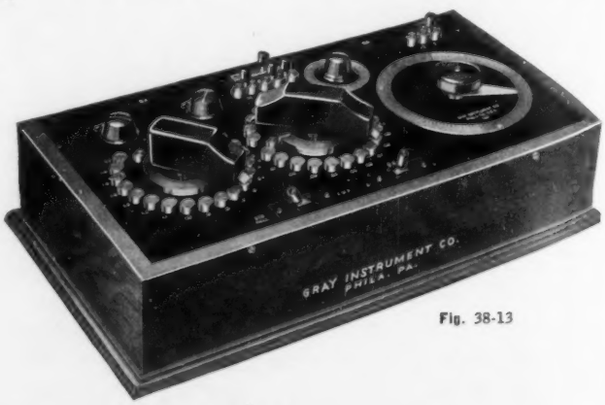

Fig. 38-13

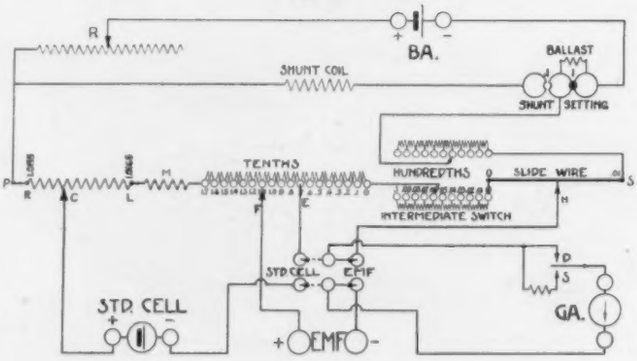

Fig. 38-14

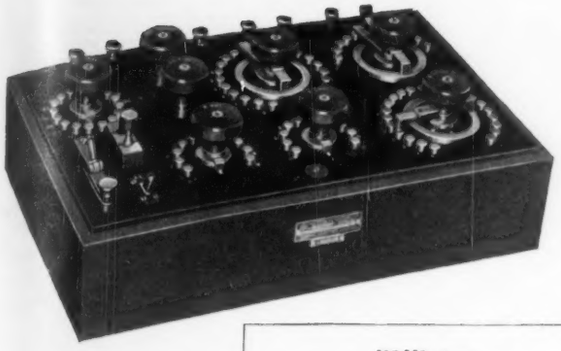

Fig. 38-15

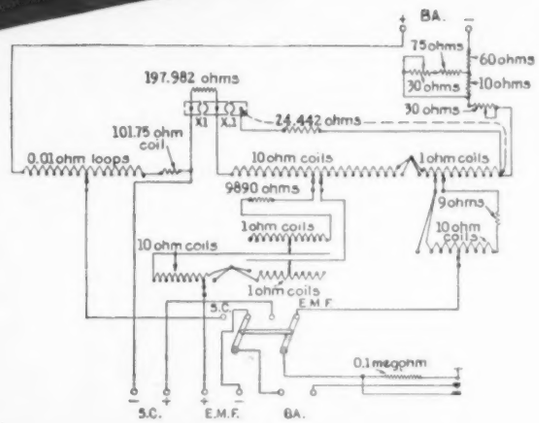

Fig. 38-16

Fig. 38-17

use of a "vernier" arrangement, *i.e.*, subdivided decades connected in parallel with sections of the main circuit, so that readings are taken directly from dial settings without need for interpolation.

The Rubicon "Type B Precision Potentiometer," Fig. 38-17, uses a modified divided circuit and there are no sliding contacts in the potentiometer circuit proper. A "novel compensation" practically eliminates thermoelectric effects in the circuits of the instrument. All electrical parts are within the case.

Fig. 38-18

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B328 **Application of Monel Metal and Nickel to Industrial Processing Equipment.** Beside giving data on the physical and mechanical properties of these materials, the booklet contains considerable miscellaneous information including instructions on the selection of suitable welding rods and other details on fabrication. International Nickel Co., Inc., 67 Wall St., New York, N. Y.

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B330 **Precision Balances.** Catalog No. 240 illustrates and describes the entire line of Roller-Smith Precision Balances. It differs from the preceding issue in that many of the attachments and accessories which are used with the balances are illustrated and described. Roller-Smith Company, 233 Broadway, New York, N. Y.

B331 **He Measures in Millionths** is the title of a 24-page booklet, Form 7185, which contains on pages 15 to 23 the story of Johansson gage blocks. Johansson Division, Ford Motor Co, Dearborn, Mich.

B332 **Geophysical Prospecting Outfit.** 12-page catalog describes the general principles of the reflection method and also the reflection equipment for geophysical prospecting. American Askania Corp., Houston, Texas.

B333 **Polarimeters and Saccharimeters.** 16-page catalog gives specifications and prices of J. & J. Fric polarimeters and saccharimeters. Sole agents in the United States are E. H. Sargent & Co., 155 East Superior St., Chicago, Ill.

B334 **Profile Gage.** Leaflet illustrates a profile gage which can be adjusted for any profile. Various styles available. Stockton Profile Gauge Corp., 165 Jackson St., Lowell, Mass.

B-335 **Electric Instruments.** Catalog GEA-602D is a 162-page book furnishing information on standard lines of switchboard, portable and laboratory instruments. Dimensions are included. General Electric Co., Schenectady, N. Y.

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B339 **Alloy Pot.** Vol. 2, No. 3 of The Zinc Alloy Pot reviews an interesting article concerning the design and development work on a small but intricate machine, the Initialator. New Jersey Zinc Company, 160 Front St., New York, N. Y.

B340 **Combustion Indicators & Controls.** Bulletin 341 describes photo-electric combustion indicators. Ess Instrument Co., 30 Church St., New York, N. Y.

B341 **The Engine Indicator Book.** A 56-page book, 6 x 9 inches, just published. It contains a description of the latest types of Trill engine indicators and accessories, with information on taking and reading of indicator cards. Book is well illustrated. Louis C. Eitzen Co., 280 Broadway, New York, N. Y.

B342 **Electric Apparatus for Measuring Velocity of Water.** List 97/1e, a 4-page leaflet, describes an instrument for measuring the velocity of a liquid in a pipe or open canal or stream. Anglo-Swiss Electrical Co., Ltd., 15 Victoria St., Westminster, London, Eng.

B343 **Magnetic Contactors.** Bul. 4401 gives the descriptions and engineering data on 2, 3 and 4 pole alternating current contactors while Bulletin 1901 gives the same information for 1 and 2 pole direct current contactors. Ward Leonard Electric Co., Mount Vernon, New York.

B344 **Recording Thermometers.** Cat. 50 describes mercury actuated recording thermometers and accessories. The various chart ranges in which it is furnished are listed. Moeller Instrument Company, 261 Sumpter Street, Brooklyn, New York.

B345 **Kathetron Regulator.** Catalog 10-A describes and illustrates the Kathetron regulator for the control of voltage below or above normal. It is characterized by extremely flexible distant control with small losses at low voltage; speed and smoothness of response and accurate setting independent of load. Roller-Smith Co., 233 Broadway, New York City.

INSTRUMENTS, 330 W. 42nd St. New York City

Please have me supplied with a copy of each piece of Manufacturers' Literature listed below.

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Name.....

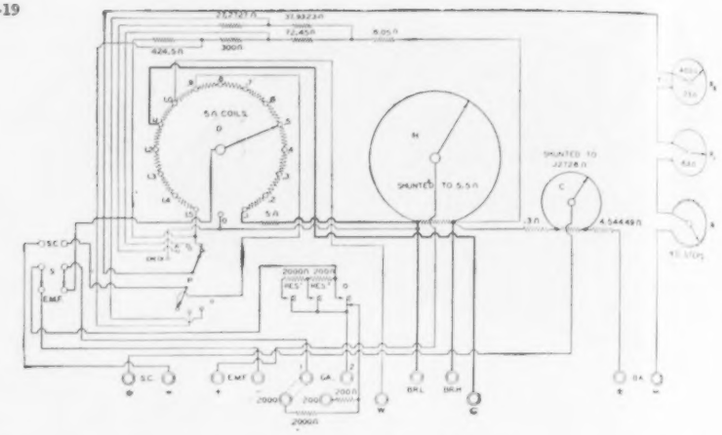
Position.....

Firm.....

Street and No......

City.....**State**.....

Fig. 38-19



Well known in American practice, the Leeds & Northrup potentiometers of the "K" series are distinguished by an eleven-turn slide wire enclosed in a rotating hood which carries the sliding contact. This slide wire length (11 feet, the longest found in commercial potentiometers) makes possible micrometric subdivision of the slide wire potential. Among features which L & N originated are a quick-transfer switch whereby current may be checked against the standard cell at any time, a range-changing device converting instrument from 1.6 to 0.16 volts range, and provision for convenient checking of all resistance values in the potentiometer circuit. Low resistance (80 ohms) is stressed by the makers as an outstanding advantage. Figs. 38-18 and -19 show the recent (1930) "Type K2" and its diagram. It has a 0.016 volt range in addition to the 1.6 and 0.16.

The Tinsley (an English instrument developed by Dr. Drysdale) differs from the above in having a "vernier" arrangement (see Fig. 38-20) whereby a graduated resistor is shifted along the main circuit by means of a double-pole switch. In this way, sections of the circuit are selected and paralleled with the "vernier" resistance, enabling the potential differences in a particular section to be read with a high degree of precision. Total resistance, 80 ohms. The Drysdale-Tinsley instrument is made up either for direct or alternating current; in the latter form, of course, it may be used on both.

The "vernier" principle has been extended in the Cambridge instrument shown in Fig. 38-21 in which there are five successive edgewise dials not only resembling a cyclometer counter but, like such a counter, reading directly in decimal order.

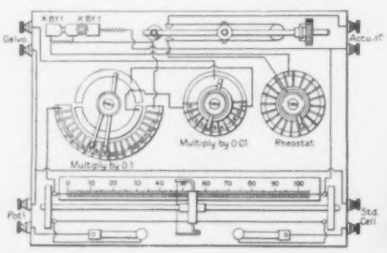


Fig. 38-20

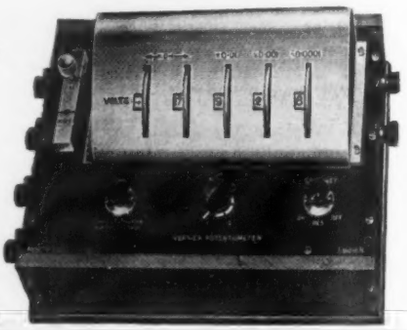


Fig. 38-21

Industrial Portable and Switchboard Potentiometers

The above potentiometers, while widely used in industry, may generally be classed as laboratory instruments since undoubtedly they all are *bench* instruments. There are on the market true null-method potentiometers designed especially for plant service, available in portable or in switchboard models. Difference of form, due to different function—or rather to specific purpose—naturally entails some limitations: the above described "bench" types generally have ranges of (1) normal, 1.5 or 1.6 volts; (2) up to 15 or 16 volts when using ten standard cells in series as the standard; (3) 0.15 or 0.16 volts by the use of a range-changing device in some makes; but on the other hand the portable and wall forms usually have but a single range.

The Brown Precision Portable Potentiometer is a readily portable instrument which nevertheless possesses a high degree of intrinsic accuracy, the slide wire being wound in a seven-turn helix on a rotatable drum, thus giving a scale with the surprising length of 8 feet. With a range of 50 millivolts, the scale can be graduated in 20-*microvolt* divisions $^1/_{20}$-inch apart. The 1935 model

Fig. 38-22

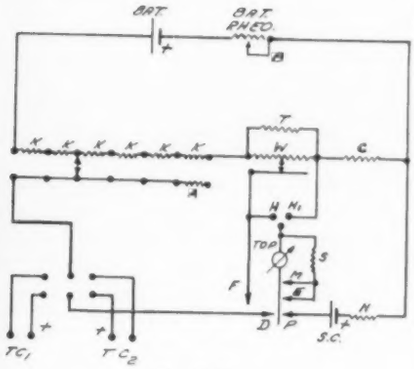


Fig. 38-23

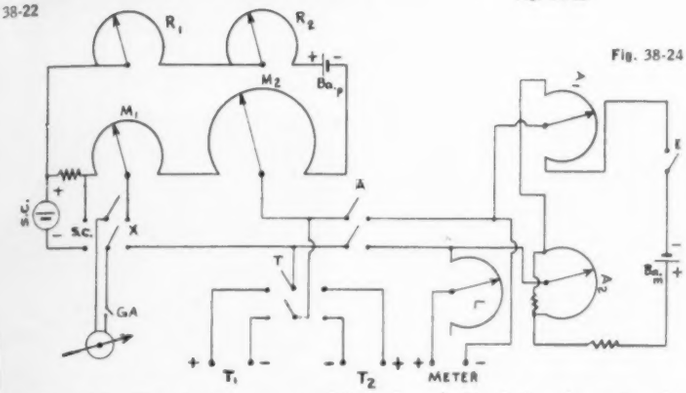


Fig. 38-24

Brown Portable, Fig. 38-22, is priced less than half of the above but has more uses, as may be seen from its diagram, Fig. 38-23: it is a test set rather than a single-purpose instrument.

The Thwing "Treasure Chest," Fig. 38-24, incorporates in a portable form a true potentiometer, whereby complete checks may be made upon the accuracy of millivoltmeters and pyrometers together with null measurements on d.-c. potentials in general, and also an adjustable source of e.m.f., separate from the potentiometer circuit, so that it may be caused to deflect an indicating instrument and at the same time perform a check on the calibrating voltage. The complete range, made available by a decade dial and a calibrated slide wire, is 101 millivolts. Provision is also made for the measurement of circuit resistances by determining the voltage drop when a known current flows.

Intended for switchboard mounting but portable as well, the Leeds & Northrup Industrial Indicating Potentiometer, Fig. 38-25, is especially suitable for that class of industrial measurements (expressible as e.m.f., of course) requiring a permanently installed, highly accurate instrument, but not requiring records or even continuous indications. This class of measurements has lately grown in importance, and other switchboard indicators were brought out recently: The Foxboro 1934 instrument usually comes with a multiple switch as shown in Fig. 38-26a, and its galvanometer needle carries a white disk (see Fig. 38-26b) for high visibility. The Brown wall type indicator has a 40-inch oil-immersed slide wire (which will be dealt with under Recorders). The 1935 model Tagliabue industrial indicator has a mirror galvanometer projecting a bright line on a screen located above the exposed portion of the scale.

Fig. 38-25

Fig. 38-26a

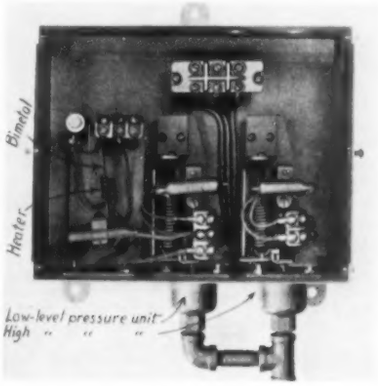
NEW INSTRUMENTS

Write Information Section, Instruments Publishing Company, for additional information.

Automatic Pump Controller

Minneapolis-Honeywell Regulator Co.

FOR elevated tank systems, the new Type L550-1 Controller employs "snubbing" principle which inhibits operation at wrong times, *i.e.*, when rapid changes of pressure result not from actual liquid head but from acceleration or deceleration of moving mass of liquid on starting or stopping pump. Instead of ordinary air cushion tank or needle-valve arrangements, a three-switch adjustable-



period electro-thermal time-delay circuit is used, whereby neither high-level switch nor low-level switch can alone stop or start pump motor. Normal adjustments are: 1. *High*. 20 sec. for heater to warp bimetallic strip enough to open snubber switch and stop pump; 2. *Low*. Approx. 2 min. from closing of low-level switch to starting pump. These constants may be altered to suit surging conditions of various applications.

Portable Cathode Ray Oscillograph

Allen B. DuMont Labs.

COMPLETELY self-contained Type 142, with 5" cathode ray tube, power supply and linear sweep circuit, has been designed for general laboratory and industrial use. Only connections are a.c. attachment plug and wires necessary to connect apparatus under test to the terminals on unit. A type 54-8 DuMont cathode ray tube, utilizing an indirectly heated cathode and equipped with two sets of electrostatic deflection plates and high-intensity screen, has a graduated scale at face to permit accurate quantitative measurements. A power supply furnishing accelerating electrode voltage as well as necessary filament and focusing voltage is incorporated, together with a linear sweep circuit having range 10-5000 cycles. Means are provided to focus spot and control amplitude and frequency of sweep voltage. Sweep circuit, of stabilized type, can be made to lock in step with a recurrent waveform if desired.

Moisture Tester

The Alpha-Lux Co.

RAPID determinations of moisture content in granular and fibrous materials are made possible by means of a simple absorption apparatus styled the "Speedy Moisture Tester." A definite weight of the material to be tested is poured into a container that resembles a cocktail-shaker. A measure of absorbent powder (furnished with tester) is poured into cap; cap is put on and clamped while apparatus is held horizontally to prevent mixing; device is shaken to mix material and absorbent thoroughly; and gage (at bottom) is read. Dial reads directly in weight-percentage of moisture. For exact determination, pause a short time, shake, read gage again, and if successive readings agree, accuracy is claimed to be comparable to that of laboratory methods. Handled case weighs 13 lbs.

Anti-lightning Protector for Watthour Meters

General Electric Co.

PROTECTION against failure due to lightning is provided for polyphase watthour meters by the new Thyrite meter-protector, designed to be mounted as part of the meter installation, intended for use on relatively long and exposed secondary circuits of 650 volts or below. Impulse-protective characteristics are such that impulse voltage is less than crest value of standard 60-cycle test voltage for new watthour meters. New device is said to offer installation advantages, being designed for mounting either on service-entrance cabinet or on meter connection-box adjacent to watthour meter, by means of standard conduit lock-nuts threaded on nipple above and below knockout hole—which arrangement places it in direct shunt relation to meter. It consists essentially of three single-pole protectors each of which is made up of a Thyrite disk and a small series gap. Steel enclosure is 5½" x 4⅛" x 2½".

5. Some Applications of the True Potentiometer

All of the instruments described in the preceding section have been dealt with solely with regard to the essential purpose of the true potentiometer: the measurement of *voltage*. All of them, of course, can be—and some are—used to measure any condition or property represented by voltage, the only change as a rule being a special scale. (The uses of volt boxes in extending the range of the instrument, and of standard resistors in making possible the measurement of current, have already been mentioned.) We come now to the use of the true potentiometer for such special purposes. An eminent authority* stated in 1931 that the use of the potentiometer in industry has increased to such an extent that nine-tenths of the potentiometers put into use each year go into plant applications. It is probable that in the years since the Director of Development of L&N made this statement the proportion has increased.

In its application to the measurement of small electromotive forces, the field of the potentiometer might seem to be limited, until it is remembered that as implied a few lines above, a number of phenomena met with in industrial work can be made to express themselves quantitatively as differences of electrical potential. Many chemical actions, for example, are accompanied by characteristic differences of electrical potential; and by properly selected electrodes these

Fig. 38-27

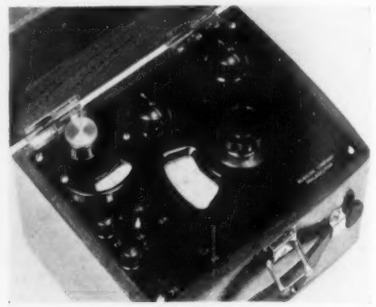


Fig. 38-28

voltages may be applied to a potentiometer circuit. Perhaps the best known present application of this type of measurement is found in the determination of acidity or alkalinity of solutions, as indicated by hydrogen ion concentration ("pH"). This system of measurement finds a continually broadening field in the determination of chemical properties in many materials undergoing industrial processes. A simple form of potentiometer designed particularly for pH determination, is included in the Thwing Portable pH Meter, Fig. 38-27.

One of the most important uses of the potentiometer principle lies in the field of pyrometry, where the potential difference set up in a thermocouple is made representative of a temperature at a more or less remote point. While such potentials may be measured with a direct-deflecting instrument, the current drawn from the thermocouple tends to affect the accuracy of the reading, and for precise measurements of this class the potentiometer is essential. Fig. 38-28 shows a thermocouple potentiometer manufactured by Rubicon. It uses the null method and is self-contained, including a standard cell, battery, rheostats and galvanometer. Note that the slide wire scale, calibrated in degrees of temperature, is double: one scale is for use with iron-constantan couples, the other for use with chromel-alumel couples.

Since the net electromotive force in a thermocouple circuit is representative of the difference in temperature of the two junctions, it usually is desirable to reduce the readings to a standard reference temperature and eliminate the effect of variations in the temperature of the junction which is not exposed to the temperature under measurement. "Cold-end compensation" may readily be effected by introducing into the circuit a combination of temperature-sensitive resistances, thermally associated with the cold junction, and adjusted to modify the potential of one end of the thermoelectric circuit with temperature changes, to a degree which will compensate for those changes and eliminate the cold junction effects from the ultimate measurement. Fig. 38-29 is a diagram of the cold-end compensating circuit used by L&N.

Since electric currents produce heat in a circuit and thermal converters may be constructed in which there is developed a temperature difference representative of the current or the power in a circuit irrespective of the nature of the current, there is thus provided a means whereby precise measurements of a.-c. magnitudes may be made through the agency of the direct-current potentiometer. An important application is the totalizing of power loads with the Lincoln thermal converter.

*I. M. Stein. Design of Potentiometers. *Transactions A.I.E.E.*, Vol. 50, 1931, pages 1302-1312.

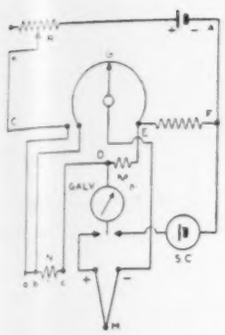


Fig. 38-29. H — hot junction; D — cold junction, with constant-resistance coil M on one side and nickel coil N on other. Nickel having a high temperature coefficient, effect is to vary electrical ratio of M and N as if point D were moved mechanically along a slide wire to compensate for temperature of junction D. (Leeds & Northrup)

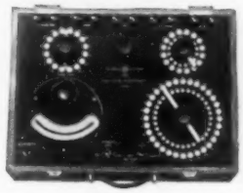


Fig. 38-30

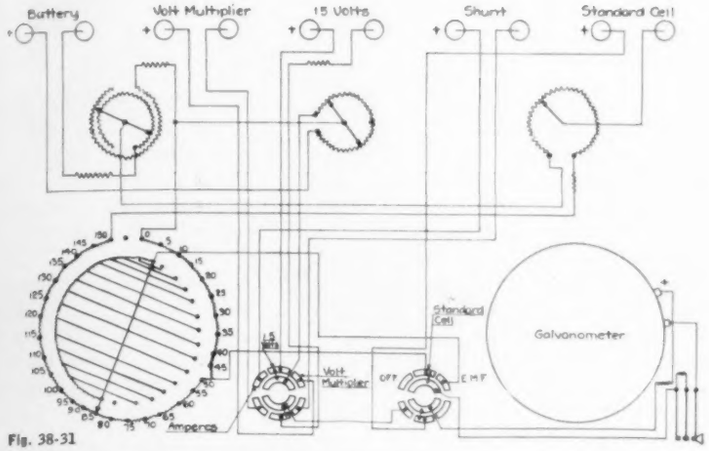


Fig. 38-31

6. Deflection Potentiometers

The true potentiometer is a null-method instrument, the electromotive force under measurement being wholly and exactly opposed by a measurable voltage, and the deflection of a detecting galvanometer reduced to zero. An interesting modification is found in the deflection potentiometer, in which the electromotive force to be measured is partially balanced by an exactly known electromotive force, and the small remaining difference read from the deflection of a calibrated galvanometer. The principle is practically identical with that of the true potentiometer except that the galvanometer circuit is maintained at a constant resistance value, giving a definite significance to the calibrated scale of the galvanometer, upon which the final readings are obtained. The General Electric Brooks deflection potentiometer is shown in Fig. 38-30; its diagram in Fig. 38-31. While the deflection potentiometer is not so accurate as the true potentiometer, it is more so than long-scale indicating instruments. It is chiefly found in plant laboratories where large numbers of direct-current indicating instruments are to be checked, and also is extremely useful in photometric work, particularly where the performance of a large number of similar light-sources is to be compared.

7. Semi-potentiometers

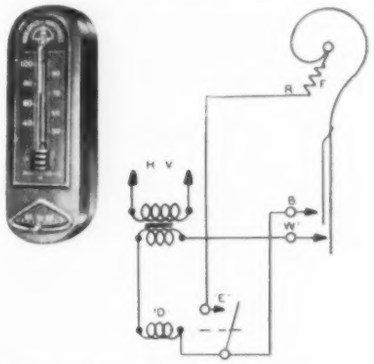
The potentiometer proper has two outstanding advantages as a measuring instrument. It takes no current from the source of potential under measurement, and it is capable of a degree of precision much higher than characterizes direct-indicating instruments. A useful class of instruments is that known as the semi-potentiometer, which, while having its accuracy limited to that of a deflecting movement forming a part of the instrument, does not draw any current from the source of potential. Instruments of this class find their widest application in the field of pyrometry,* where the precision of a good deflecting movement is often sufficient, but where it is desired to keep the current in the thermocouple circuit at the lowest possible value. While there are several types of instruments in this class, the general principle may be said to lie in establishing the value of a current in a potentiometer circuit by means of an indicating instrument, and then applying the balance principle in measuring the unknown electromotive force against the potential drop in a known part of the circuit. In some forms a single movement serves the dual purpose of indicator and galvanometer, while in others two distinct deflecting elements are used. The commercially available semi-potentiometers some years ago were pyrometers; examples: the "Brown Heatmeter," and the Northrup "Pyrovolter"—both

*Harrison and Foote. A Precision Galvanometric Instrument for Measuring Thermoelectric E.M.F.'s. *Transactions A.I.E.E.*, Vol. 39, 1920, page 371.

"Heat Accelerated" Type House Thermostat

Minneapolis-Honeywell Regulator Co.

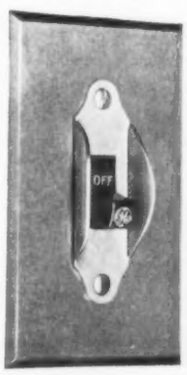
DEVELOPED with special consideration of distinctions between "temperature control" and "heat distribution," this new type (T17-1) has for chief purposes (1) elimination of "cold 70," (2) even distribution of heat not only in room where installed but throughout house, (3) automatic compensation for outdoor conditions, (4) ready adaptability to type and size of heating plant and to house construction and insulation, (5) fuel economy. Makers'



"Series 10" circuit has been modified by placing small heater *F* (see diagram) in holding circuit to accelerate breaking of *W* contact. However, *B* contact must be broken by normal temperature rise at thermostat before auxiliary heat is applied, the manner of application being said to account for "superiorities of the T17-1 over conventional types of heat anticipating thermostats." To energize relay *D* and start burner, *B* and *W* close in conventional manner. When *D* closes, holding contact *E* is made, and as soon as *B* opens, circuit is then from *W* through secondary of transformer, *D*, *E*, *F* and back to *W*. Heating element is thus shunted out as long as *B* remains closed. Heater being in thermostatic coil post, burner will operate approx. 6 min. after *B* opens—exact time depending on rate of temperature rise.

Trigger Guard Protects Flush Tumbler Switches

General Electric Co.

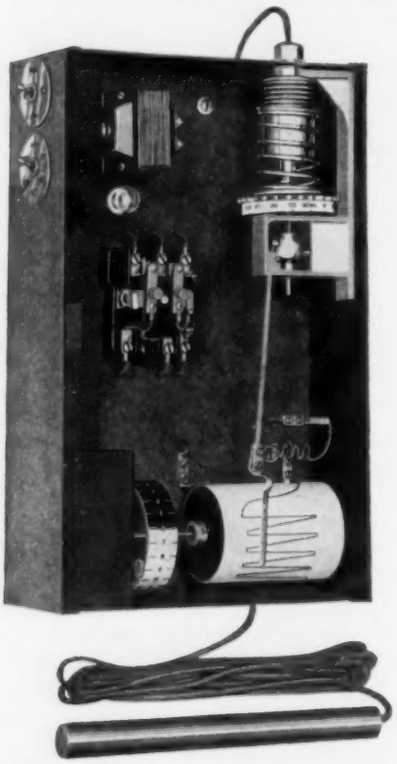


DESIGNED to protect triggers and mechanisms of relatively exposed flush tumbler switches in exposed locations such as shops, this new guard is made of heavy brass with side rails which shield the trigger. It is conveniently mounted on the flush plate simply by removing the screws holding the plate to the switch and then attaching guard and plate by means of the same screws. Finished in brush brass.

Temperature Controller with Adjustable Time Cycle

Jas. P. Marsh Corp.

DESIGNED for controlling temperature in a building or in certain zones thereof, the "Tritrol" Regulator automatically varies the time of starting heating system in morning, and



of shutting it down at night, to compensate for changes in out-side temperature. During the day, it maintains an intermittent flow of heat to the building, the periods automatically varied in inverse proportion to outside temperature. Means are provided for adjustment for variations in climatic conditions, load, or desired indoor conditions. Typical application, control of steam flow to a building where steam is purchased from an outside source: valve in steam main is operated periodically, periods varying with outside conditions. During each period steam flows into system until all radiators get their share, thus insuring even heat throughout building. Where system is slow-circulating such a method is obviously advantageous; where steam circulates freely the use of a slow-acting valve permits practically constant but modulated flow. A motorized, solenoid-operated or pneumatically-operated valve may be used as desired. New device is said to be "ideally suited to control an oil burner. Definite firing periods insure maximum efficiency of operation." The periods are of duration to heat entire system, eliminating cold sections. Where several burners are used in one building, or in a group of buildings, they may be controlled individually or collectively from a central point. New "Tritrol" is also suitable for operation of a stoker: definite firing periods insure maintenance of hot coals in firebox; regulation of morning starting and night shut-down according to outdoor conditions restricts heating to hours during which building is actively occupied.

Fig. 38-32

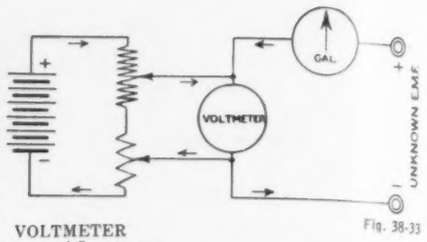


Fig. 38-33

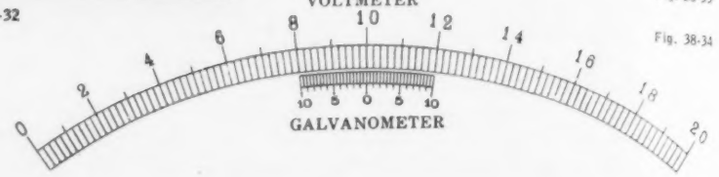


Fig. 38-34

withdrawn, as was also the 1916 Weston instrument of this type. Today, semi-potentiometers seem to be coming back into vogue, both for pyrometry and for other purposes. The G.E. Thermocouple Potentiometer, Fig. 38-32, is of this type. In common with all semi-potentiometers it dispenses with a standard cell; it has three ranges, of 6, 30 and 60 millivolts and also a temperature scale calibrated for "G-E special-alloy" thermocouples; and is entirely self-contained, including a battery of two dry cells, in a 16" × 12" × 9" case. A general-purpose semi-potentiometer is the "Rhodes Potentiometer Voltmeter" made by Sensitive Research Inst. Corp. Its circuit diagram, Fig. 38-33, is self-explanatory and applies in its essentials to all instruments of this class. The instrument itself, however, is probably unique in that the millivoltmeter and galvanometer moving-elements use the same magnet, their pointers being superposed and the scales being arranged as shown in Fig. 38-34.

8. Dual Application of the Potentiometer

In certain classes of measurement, such as determining resistance by the fall-of-potential method or checking wattmeters, it is desirable to measure two electrical magnitudes simultaneously or nearly so. Where conditions are such that one of these may be held to a constant value and measurement performed upon the other, a single potentiometer may sometimes be made to do the work of two instruments. The potential difference representing the magnitude held at a steady value is balanced against the potential at a selected point on the instrument; and, by a throw-over switch, the variable magnitude is quickly applied to the regular potentiometer circuit for measurement. These operations may be performed in rapid succession, and repeated until a steady condition is assured, so that with a single instrument it is possible to obtain the precision of a potentiometer in the determination of both magnitudes. A diagram developed by one of the authors* for this purpose is shown in Fig. 38-35. The principle is similar to that of the "double potentiometer" due to White (where indeed it is developed to a higher degree of refinement) but the idea of the arrangement illustrated is to make this principle available to the user of a standard L&N "Type K" instrument. Space does not permit describing the White potentiometer, which is but one of the possible refinements.

*P. A. Borden, An accessory device for Potentiometers. *Journal Optical Society of America & Review of Scientific Instruments*, Vol. 13, Nov. 1926, pages 601-602.

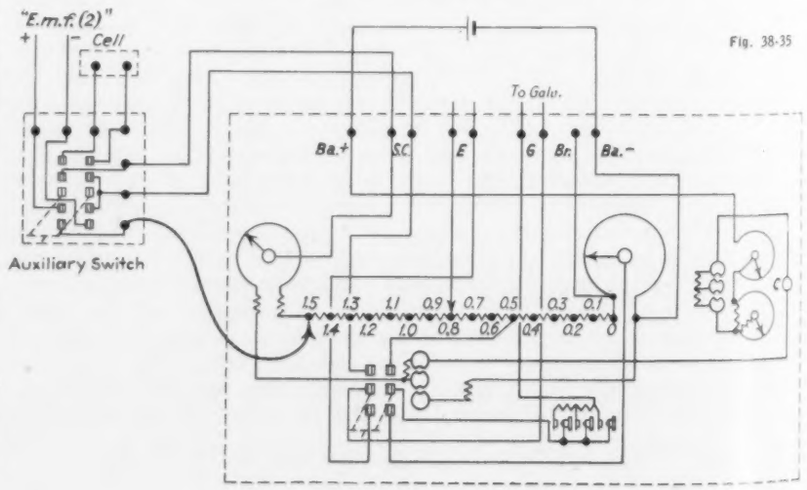


Fig. 38-35

Resistance Decades

HIGH-FREQUENCY TYPE

Single-dial decades for incorporation into laboratory or test equipment.

Low phase angle and shielding permits use at all audio frequencies and low radio frequencies.

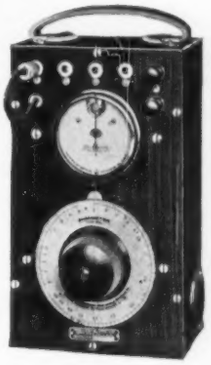
Each dial has 11 steps (0 and 10).

Type 510 Decade-Resistance Units

PRICE	
Type 510-A 0.1-ohm steps..	$ 8.50
Type 510-B 1-ohm steps..	8.50
Type 510-C 10-ohm steps..	8.50
Type 510-D 100-ohm steps..	8.50
Type 510-E 1000-ohm steps..	13.00
Type 510-F 10,000-ohm steps..	16.00

GENERAL RADIO COMPANY

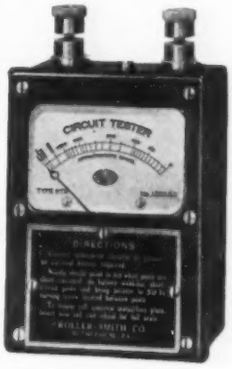
CAMBRIDGE A MASSACHUSETTS



ROLLER SMITH
TYPE COM OHMMETER

Direct reading, self-contained. Range 0-50000 ohms. Readable to .02 ohm. A rapid and accurate ohmmeter for production work.

Send for Cat. J-123-5.



TYPE HTD CIRCUIT TESTER

Direct reading, self-contained. Range 0-10000 ohms. A fine little instrument for testing circuits and measuring resistances.

Send for Cat. J-123-5

ROLLER-SMITH COMPANY
Electrical Measuring and Protective Apparatus

Main Office — 2132 Woolworth Bldg., New York
Works — Bethlehem, Pennsylvania

Sales agencies in principal cities in U.S.A. and Canada.

Vibration Velocity Indicator

General Electric Co.

PORTABLE, self-contained, requiring no tubes, batteries or external power, and operating at any angle from horizontal to vertical, this novel electromagnetic device for measuring the velocity of vibration of an object in the noise-producing frequency range consists of two units connected by a flexible cable as shown. The "velocity unit" transforms mechanical vibrations to voltage variations by means of a coil moving in a permanent magnet field. Coil is magnetically shielded. Vibrations to be measured are transmitted to coil by duralumin contact rod extending from front of cylindrical case. "Meter unit" consists of an impedance matching transformer, a suitable resistance ratio network, and a Rectox operated "Type DO" microammeter with a scale marked directly in mils/sec. vibration velocity. Velocity scale allows attainment of great sensitivity throughout noise-producing vibration range because, for same amplitude of vibration, velocity increases in direct proportion to increase in frequency. (In machinery in general, the higher the frequency of vibration, the smaller the amplitude, so that velocity, which is proportional to product of frequency and amplitude, tends to remain constant.)

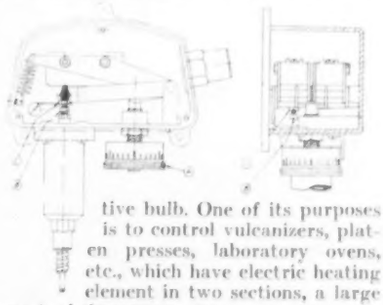
One type of application ("Go and No Go") is illustrated by a production line of motors where one acceptable motor has been measured for vibration velocity. Another lies in detection of unknown vibration velocities: various parts of an automobile under different conditions. A connection for headphones is provided and complex sounds can be differentiated by ear. (Scale reading being affected by insertion of headphones, velocity measurements should not be taken while these are in circuit.) An attachment is obtainable whereby instrument can be permanently mounted and its output used to sound an alarm or shut down machinery when velocity exceeds a predetermined value, or for recording.

Operating Limits. — Total *allowable travel* of moving coil system of velocity unit is 0.060": limited by mechanical stops. An attachment for measurement of amplitudes >0.06" is being developed. Two scale multiplier switches on the "meter unit" provide *scale range* for all ordinary purposes: Four possible positions of these two switches provide scale multiplications of x1, x4, x10, x40, providing mils/sec. vibration velocity ranges of 0-250, 0-1000, 0-2500, 0-10,000. In terms of double amplitude at 60 vibrations/sec., these scales provide amplitude ranges of 0-1.88, 0.-7.5, 0-18.8, 0-75 mils. *Minimum frequency* is 2.5 cycles/sec.; *maximum frequency*: Scale readings are said to be accurate to ±5% at all frequencies up to 1000 vibrations/sec.

Double Switch Thermostat

Wilbin Instrument Corp.

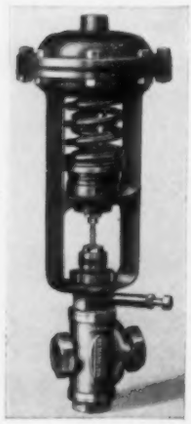
COMBINING in one unit the functions of two, this new thermostat is designed to operate two separate circuits from a single temperature-sensitive bulb. One of its purposes is to control vulcanizers, platen presses, laboratory ovens, etc., which have electric heating element in two sections, a large one to bring apparatus up to temperature and a smaller one to hold within close limits. Illustration shows required arrangement. Adjustment knob *A* determines high point; while differential between the two switches of unit is adjusted by means of screw *B* and locknut *C*. Various combinations are possible to meet requirements of different applications.



Pressure Regulator

Mason-Neilan Regulator Co.

THIS new pressure reducing regulator, known as No. 505 Series, is equipped with non-corrosive stainless steel ball bearings which roll up and down to minimize valve stem travel friction, and also turn freely under the spring adjusting screw to facilitate pressure settings. Multiple springs permitting use of larger diaphragms are said to increase sensitivity and accuracy. A self-aligning spring button prevents spring tilt and side sway from interfering with smooth operation. These regulators are equipped with the "Centroguide Valve," in which plug is centrally guided at top and bottom of body to minimize wire drawing and cutting of plug and seat rings. Grease-sealed stuffing boxes optional.



Steel Abnormality Tester

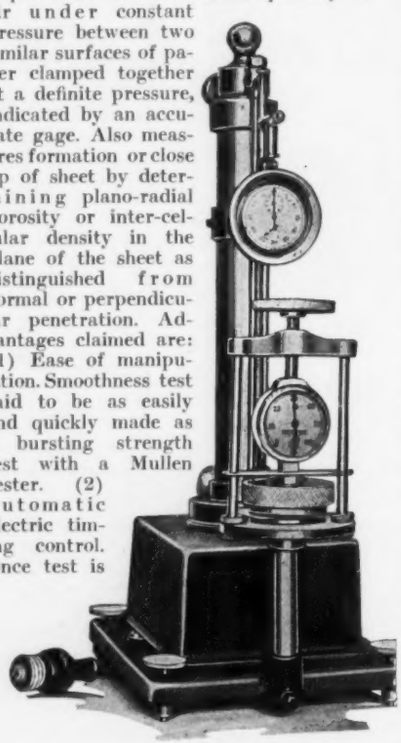
Ferrous Magnetic Corp.

COMMERCIAL production is announced on instrument generally similar to that described in Dr. Specht's article announcing the new thermo-magnetic method (*Instruments*, Sept. 1934, pages 182-184). It is furthermore stated that industrial model will have three distinct functions: (1) Quantitative measurement of degree of abnormality in each specimen; (2) determination of grain size; (3) determination of carbon content. For all these tests the new instrument works automatically and gives scale readings. Tests being made on miniature ingots (⅜" x 9½") a heat of carburizing steel may be reported on while it is still in the furnace.

Paper Smoothness and Formation Tester

Williams Apparatus Co.

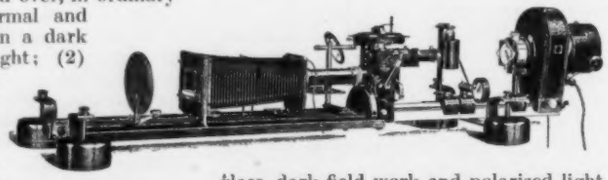
THIS new Williams Electric Smoothness and Formation Tester for Paper measures smoothness by noting time required to force a definite quantity of air under constant pressure between two similar surfaces of paper clamped together at a definite pressure, indicated by an accurate gage. Also measures formation or close up of sheet by determining plano-radial porosity or inter-cellular density in the plane of the sheet as distinguished from normal or perpendicular penetration. Advantages claimed are: (1) Ease of manipulation. Smoothness test said to be as easily and quickly made as a bursting strength test with a Mullen tester. (2) automatic electric timing control. Once test is started, no further attention is required until watch is electrically stopped and elapsed time registered. (3) Accuracy. Slight difference in surface smoothness readily noted, and exceedingly close check tests on the same sample said to be easily obtained.



Large Epi-microscope and Camera

Carl Zeiss, Inc.

FOR work with incident light this new optical bench styled "Zeiss Neophot" is equipped for: (1) *microscopic observation and photography* at magnifications of 50-2000 × and over, in ordinary bright field, with normal and oblique illumination, in a dark field, by polarized light; (2) *low-power survey photography* at 4-26 × magnification, with normal and oblique illumination; (3) *Macro - photography* of large objects with a photographic objective, full-size and at slight magnification or reduction. Microscope stand is low-built, with convenient arrangement of all controls, and has highly stable stage accommodating heavy specimens. Illuminator combines various possibilities of bright-field work with prism or plane-glass, dark-field work and polarized light illumination; and change from one type to any other can quickly be effected without disturbing adjustment of object or focus.



Density Comparator

By Everett W. Melson*

DESIGNED for accurate and rapid quantitative spectrographic analysis, this accessory instrument to any spectrograph measures intensities of spectrum lines by photo - electric means and indicates results directly on a scale. For work involving measurement of but a few selected lines (usual in quantitative spectrography) it surpasses recording types of micro - photometers in rapidity and economy. It is free from operator's personal equation and fatigue effects which impair accuracy of visual photometer measurements; obviates waiting for the development of photographic paper or film; and may be used for plates taken with any size, type, or make of spectrograph. Complete equipment consists of a projection system, a photoelectric receiver, a voltage regulator and a sensitive galvanometer. The current for the standard unit is 110 volt, 60 cycle a.c. Provision is made for other voltages and frequencies.

Illuminator, located inside housing, consists of a 200-watt monoplane filament lamp equipped with a reflector, and is focusable. Since measurement depends on intensity of illumination there is provided a regulating transformer which delivers a constant voltage of 115 volts, even though line voltage varies from 105 to 130 volts.

Spectrum plate is mounted on a mechanical stage carried by a horizontal guide directly between illuminating chamber and projection lenses. Horizontal and vertical adjustments are provided. A condensing lens system with heat-absorbing filter, mounted inside housing between light source and plate, illuminates an area about 1" square. Outside housing is focusable projection lens system which, with aid of two mirrors (one adjustable) throws a magnified image of illuminated area onto large inclined white screen. Double imagery is avoided by use of first-surface mirrors. Projected image is visible in an ordinary lighted room, permitting easy selection of a desired line.

Light from projected beam passes through a narrow vertical slit in inclined screen and falls directly upon photocell. Slit is narrower and shorter than projected image of a spectrum line, so that when latter is positioned over it, light reaching cell is that which has passed through spectrum line. Two red glass filters prevent interference from stray light scattered by reflecting surfaces; a narrow open slot between them allows white light to pass through spectrum line while rest of field is illuminated with red light.

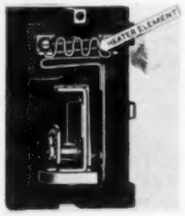
In receptor system, a single Weston Photronic (self-generating) cell is mounted behind narrow screen slit. Its output is measured by a high-sensitivity deadbeat reflecting galvanometer. To steady galvanometer mirror where building is subject to heavy vibration, there is listed as an accessory the Brevoort Modified Julius Suspension (*Instruments*, May 1931, pages 277-278).

*Bausch & Lomb Optical Co., Rochester, N. Y.

Room Temperature Control

Penn Electric Switch Co.

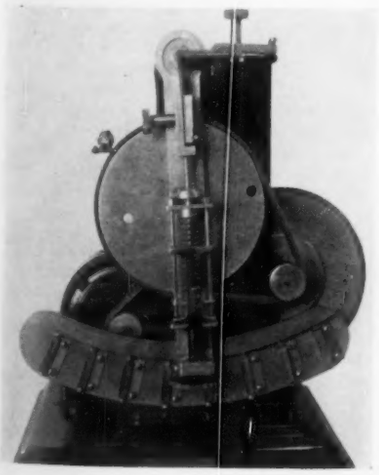
ANTICIPATING room temperature change, the new "Penn Temtrol" is said to maintain a uniform temperature within ¼°F. at a constant level 6" to 12" above instrument level, regardless of outside temperature change. Control circuit current generates heat which combines with heat from surrounding air to actuate thermostatic element and shut down burner after a comparatively short operation period. As element temperature is always above room temperature, heat transfer from element to surrounding air is accelerated and burner is started before room temperature drops. Comparatively short, frequent, "shots" of heat are automatically lengthened in colder weather by a lowered temperature at instrument level, caused by increased floor-ceiling temperature gradient. Low mounting, said to be available "only with precision instruments such as Temtrol," is said to divide this gradient above and below instrument setting to "attain maximum comfort in four-foot zone." Heater is furnished in various sizes for various heating control circuits. For "Day-Nite" control a sub-base, with separate heater to raise instrument temperature above room temperature, is inserted under Temtrol. Sub-base heater is energized by setting a separate timing control, "Timetrol," which de-energizes heater at end of desired period. New device is especially designed for low mounting: heavy Bakelite, tamper-proof construction, top adjustment, no thermometer.



Carlson Score and Built-up Fibre Board Tester

Thwing Instrument Co.

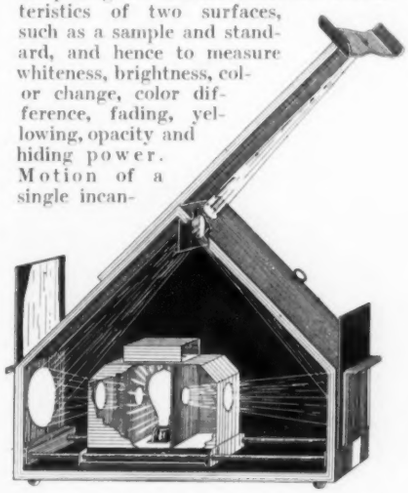
BY means of this new instrument the relative serviceability of different fibre boxes can be measured and the relative values of different kinds of scores or creases determined. It applies a combined action of tension, tearing and repeated bending to a specimen bent over and drawn firmly against a sloping edge. A scored specimen representing material from an edge of a fibre box may be bent initially approx. 90°, bend being parallel to and at score, so that score may be in contact with sloping edge during test. Number of times specimen is bent through predetermined angle and the maximum tension applied before specimen is torn apart indicate amount of rough handling which box will withstand. Subjecting all specimens to same *initial* tension is accomplished (after specimen is fastened in the fixed and movable clamps) by turning ratchet until desired amount of tension is indicated. The *maximum* tension is registered on a calibrated vernier. A counter registers the number of bending cycles to which a specimen is subjected. Intermediate pulleys between motor and main shaft serve to vary speed of operation.



Hunter Reflectometer and Color Comparator

Henry A. Gardner Labs.

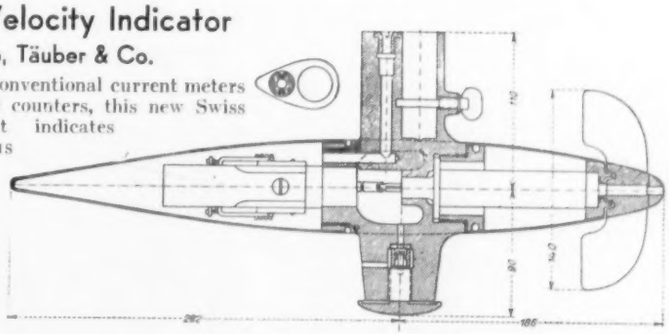
APPLICABLE to problems of color control, this new instrument is a pattern mirror photometer for comparing the diffuse reflection characteristics of two surfaces, such as a sample and standard, and hence to measure whiteness, brightness, color change, color difference, fading, yellowing, opacity and hiding power. Motion of a single incandescent lamp between these surfaces provides variable illuminations upon them. Observer may vary position of this lamp and watch for photometric balance between two surfaces. Comparisons may be made with artificial daylight, red, green, or blue color filters.



Water Velocity Indicator

Trüb, Täuber & Co.

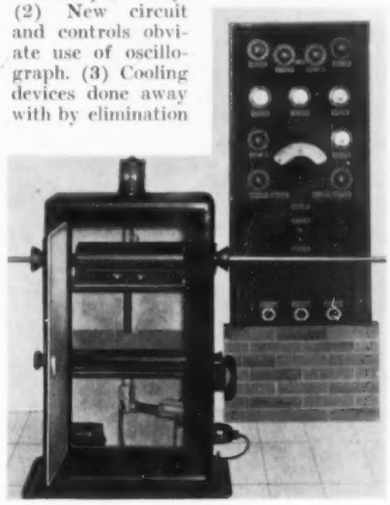
UNLIKE conventional current meters operating counters, this new Swiss instrument indicates instantaneous velocity on a remote portable instrument. Principle is that of electric tachometer: small magneto is driven by propeller and its d.c. output (< 1 milliwatt) measured on high-sensitivity temperature-compensated galvanometer with knife-edge pointer and antiparalax mirror scale. Calibration is linear throughout practical range. All sources of trouble seem to have been eliminated in design and construction: immersion for long periods at "great depths" being declared practicable.

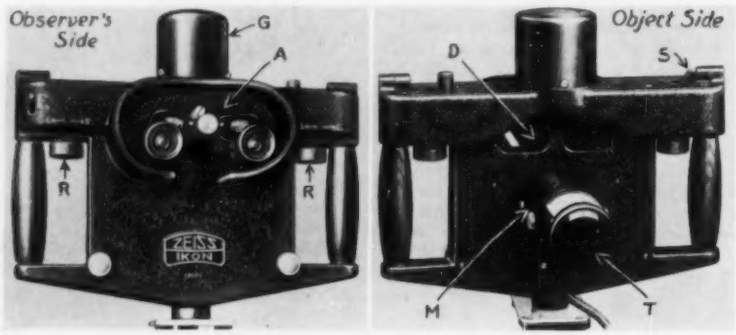


Magnetic Inspector

Ferrous Magnetic Corp.

FOR rapid continuous inspection of bar stock, tubes, etc. New model announced. Features: (1) Materials inspected to very end, which could not be done previously. (2) New circuit and controls obviate use of oscillograph. (3) Cooling devices done away with by elimination of need for a physical comparison standard. (4) Circuits now closed throughout test hours; hence, no more delay cutting test coil on and off when materials pass in and out. (5) Speed may be regulated between 75 and 100 ft./min.; previously 10 to 35 was average best. (6) Detector and signaling devices now constructed and positioned to give operator complete control of inspection routine. (7) Single bell stroke and simultaneous flashing of signal light—both mounted on apparatus—indicate appearance of a defect. (8) An additional color-light signal system indicates extent of defect; an additional bell stroke indicates end of defect leaving detector circuit. (9) Throughout these signal indications a large switchboard instrument is in operation, its scale deflection indicating degree of defect. (10) In addition, emery wheel, paint gun or high-speed shears may optionally be installed for automatic marking or cutting. (11) Inspector now having full control, direct orders to segregate or grade tested material are made possible; heretofore, with oscillator type indicating circuit, operator was remote (dark-room) from inspection operation proper.





Binocular-vision Disk Stroboscope

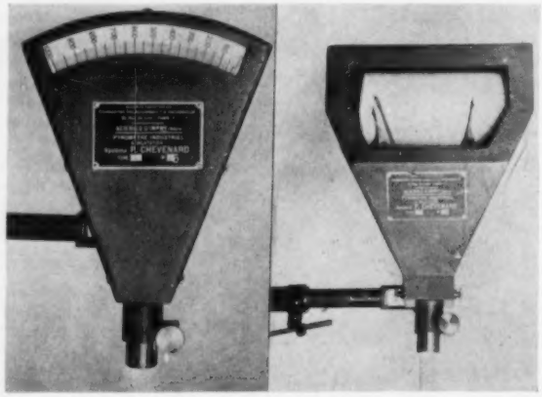
George Scherr Co.

PORTABLE or adjustably mounted on a tripod, this new Zeiss-Ikon interrupted-line-of-sight stroboscope is furnished with a set of seven slotted disks (1 to 24 slots in each) affording an exceptionally wide total speed range. Unique feature is adapter plate *A* for fastening a pair of prism binoculars in front of viewing apertures when close-up of airplane propeller, *e.g.*, is desired. Electric motor drive; thumb-regulated governor; built-in shaft-speed tachometer.

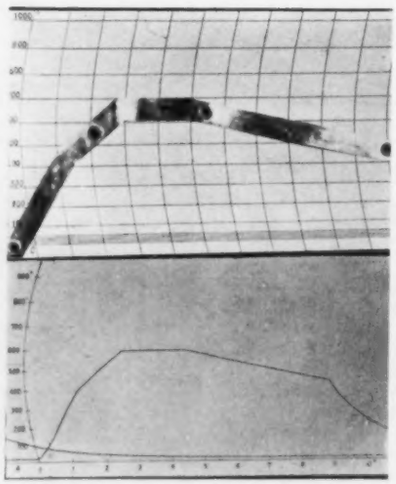
Industrial Expansion-type Pyrometers

The R. Y. Ferner Co.

DESIGNED by Dr. Chévenard and made by the Aciéries d'Imphy. Principle: difference of expansion of a Pyros rod and enclosing fused silica tube. Pyrosalloy is unaffected by repeated cycles of heating to 2000° F. and cooling. Three ranges: 300, 600 and 1000° C. Four lengths of silica tube: 0.450, 0.600, 1.0 and 1.4 m. O.d. of longer tubes, 16 mm.; of shorter ones 8 mm. The lengths of the Pyros standards vary from 100 to 225 mm. Five types of instruments: Type A is plain indicator. Type B indicates and also controls or signals by contacts on two arms pivoted in same axis as pointer. Upper arm is set at desired temperature. Pointer has two contact points, second of which acts soon after first if first fails to break heating circuit. If, on low point of upper-arm control circuit, heat should not be turned on, pointer continues to move toward lower arm and through it closes alarm circuit. Optionally, if automatic control is not desired, upper and lower arms are used in conventional way to give two different signals. Other three types have recording drum driven by clockwork. Type C is plain recorder. Type E records and is also equipped with two arms like Type B. With Type F, a desired temperature cycle can be imposed on furnace or bath, by means of a thin silver strip on drum, representing the temperature curve desired. Needle makes contact with this to open and close heating circuit as in Type B, but setting point at any moment is determined by silver curve. A rheostat can be used in heating circuit to give just enough current to maintain highest temperature desired. Use of fused silica tubes is said to have advantage of small expansion, small thermal conductivity, rigidity at high temperatures, and radiant heat transmissivity permitting rapid heating of Pyros standard. Though fragile in appearance, tubes are said to withstand severe plant service. *Refrigeration Service*: These pyrometers can also be used for this service by making lower contact arm the one which operates the relay on control circuit.



Type A Type E

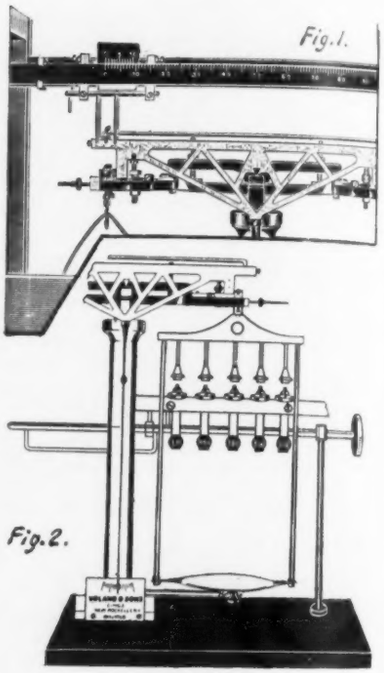


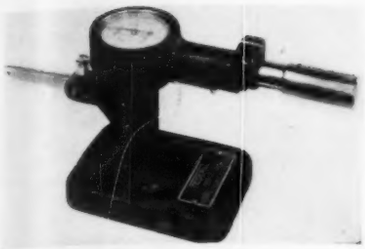
Type F program device, and result.

Analytical Balance

Voland & Sons, Inc.

HANDLING of all weights and riders below 2 g. 100 mg. is done away with by use of "Voland Patented Vernier and Grid." By means of vernier (Fig. 1) the use of fractional weights below 100 mg. is entirely eliminated: By moving a single unit (disk between vertical shifting pins directly over left end of beam) load in pan from zero to 100 mg. is recorded, result in mg. and tenths being indicated on graduated strip by vernier. This strip is horizontal and at eye level, permitting accuracy in reading and natural sitting position for operator. Vernier and sliding disk are operated by knurled knob at lower right hand side of balance cabinet, and can be used while beam is in motion. A magnifier for easier reading of vernier can be attached. Grid (Fig. 2) is a patented construction within and behind right hand hanger of balance, by use of which weighings from 100 mg. to 2 g. can be made. Weights are placed within the hanger, where they do not come in direct contact with any other part of the balance, and therefore are not subject to friction. In operating grid, upper knob on right side of balance case is used to shift rod until the small lever is over selected abutment. It then is lowered, displacing weight on grid. Should this not be right weight, by placing lever under the abutment weight can be raised individually. If a series of weights has been displaced, by engaging large lever with all abutment lowered, and then raising it, all weights are removed from grid simultaneously. With these attachments, is is said, fast weighings can be rapidly made without displacing either rider on beam or weights on grid. Rider or weights can readily be moved by user for replacement or adjustment. New balance, it is said, will withstand ordinary laboratory usage without impairing accuracy.





Small Hole Gage

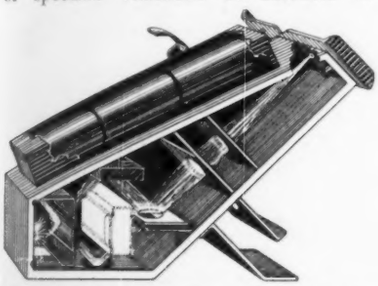
Federal Products Corp.

FOR measuring small diameters as well as detecting out-of-round, bell mouth, and taper condition, this new Federal Small Hole Gauge, Model 166, is a two-point contact, dial micrometer, plug gage with plugs (furnished for any size from 0.200" to 1½") that can be changed in less than one minute. Standard length range is 2¾" to 5¾"; other lengths can be supplied. Bench type (illustrated) can be operated either by hand or by foot lever control. Also, it can be furnished with pistol grip in place of stand. Indicator is graduated in 0.0001" and dial is movable for setting.

Hunter Glossmeter

Henry A. Gardner Labs.

TO obtain a numerical rating for gloss and provide a description of surface texture, this small, portable, self-contained photometer measures the intensity of specular reflection of surfaces to



which it is applied. The gloss value obtained is independent of the diffuse, or body reflection of the surface tested. For this reason a numerical gloss figure does not depend upon the color and brightness of the sample, but only upon the surface's mirror-like reflection. Applicable to the gloss problems of the paint, paper, textile, ceramic, metal finishing, and other industries.

A Small Littrow Quartz Spectrograph

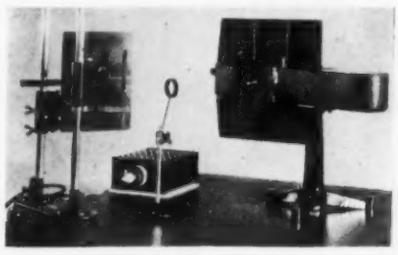
By Everett W. Melson*

FOR industry and education, this new instrument is simple in design, sturdily built and easily portable. Range covered is from 2100 to 7000 A.u. and linear dispersion between these limits is approx. 150 mm.; and length of the individual spectrum lines on photographic plate is 3 mm. Entire range being covered in a single spectrogram, no adjustments of lens or prism are required (as in larger instruments of Littrow type) and rigidity and permanence of adjustment are achieved since optical system has no movable parts. Not intended to replace medium or large spectrographs for work on complex spectra where close lines require high resolving power and dispersion for satisfactory separation, this instrument affords a longer and more easily read spectrum and a greater precision of measurement than any other small spectrograph. For simple spectra (especially non-ferrous metals) it provides an exceptionally rapid tool for analysis, particularly if desired information can be obtained in the short wave-length portion of the ultraviolet, where the linear dispersion and resolving power of a quartz spectrograph are much greater than at long wave-lengths. Examples: detection of Ag, Cu, Bi, Sn and Sb in pig lead; Ag, Pb and Fe in copper; Sn, Pb, Cd and Mn in zinc-base die casting alloys. Among other uses: detection and identification of weighting in silks, and of metals in other fabrics; study of inorganic constituents of plant and animal tissues; analysis of dissolved solids in water; analysis of glass and other ceramic materials for impurities.

For analyzing explosion reactions in internal-combustion engines, this new instrument is easily mounted on engine block in position to receive light from a quartz window fitted in cylinder wall or head, and spectra obtained permit accurate measurement and identification of emission lines and bands produced by explosion. Under favorable conditions it can also be used for quantitative work, the requirement being that the spectrum lines of the element to be determined must be clearly separated from neighboring lines of other constituents. It is ideally suited to absorption analysis, where too high dispersion is often a hindrance rather than a help, and where it is desirable that all the required information be contained on a single plate.

Optical system is of crystal quartz of the "Auto Collimating" type, in which a prism with a metallic reflecting back is used and a single lens serves both as collimator and camera lens. Light entering the slit is rendered parallel by the lens, is refracted on entering the prism, and upon striking metallic coating is reflected back along a path nearly parallel to entering beam. It is again refracted on leaving prism and is focused as a dispersed spectrum upon photographic plate by same lens that collimates entering light. This design permits, for a given overall length, much greater focal length and linear dispersion than in quartz spectrographs of ordinary type. Four standard slits are provided (2, 5, 10 and 20μ) cut in a properly protected silver coating deposited on a single quartz slide. Slit widths are indicated in microns on face of slide. Advantages of this type are: stability, parallelism of edges and ease of cleaning.

Plate holder is a standard Graflex type, 5 x 7" size, especially adapted for use on this spectrograph. Septum between two slides has been removed to permit one slide to be used for loading and the other for exposure after holder has been placed in spectrograph. Plate is bent over curved guides to meet focal curve of lens and a scale indicates location in the vertical direction and provides for proper spacing of exposures.

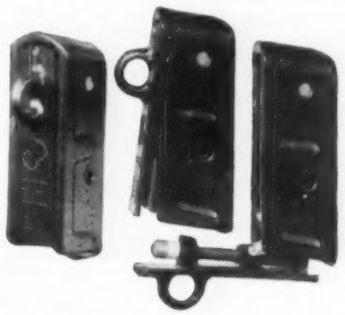


*Bausch & Lomb Optical Co., Rochester, N. Y.

Enclosed Indicating and Drop-out Fuse Cutout

General Electric Co.

PORCELAIN-enclosed cutout shows open circuit, either by conventional drop-out method or by a new method: partially opening bottom of door. New indicating feature allows door bottom to protrude only about 1¼", therefore live contacts and mechanism are not exposed to weather. Rated at 5000 volts, 60 amps., with an interrupting capacity of 1500 amps. (rms.), new device is convertible from the new indicating action to drop-out action, by removing



(with fingers) a small wire yoke. When device is employed as conventional drop-out cutout, a time-delay feature (spring-latching mechanism) causes current to be broken in fuse holder before contacts open, thus preventing burned contacts and possible destruction of the cutout. A spring-driven lever arm to which fuse link is fastened pulls even largest sizes of fuse links out of fuse holder when currents are too small to produce expulsion action, thus assuring indicating or drop-out action. Lever forms part of door hinge; both are electrically isolated when door is open.

Bausch & Lomb Optical Co., Rochester, N. Y., has prepared for free distribution suggested plans for two photomicrographic dark rooms. One of these calls for the smallest usable space 6'x6'; the other for an average size dark room, 9'x12'. Layouts show suggested arrangement of sink, table, print-washer, drainboards, etc.; and give estimated costs for carpentry, painting, plumbing and wiring. Materials needed are listed and their total cost estimated. The plans are printed on one side of a poster, on the other side of which the rules for using the dark room are printed, with a bold caption, "Knock Before Entering."

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Time-delay Demand Relay

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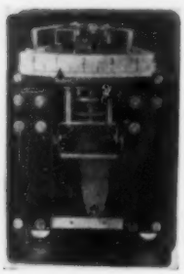
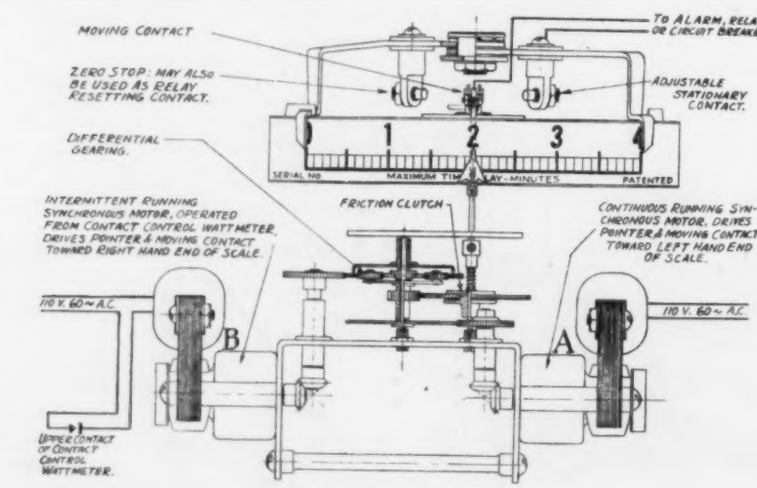
DEMAND LIMITATION problems require equipment which will automatically sound a warning or shut down non-essential loads when electrical energy consumption passes an arbitrary limit during a predetermined interval of time. For greatest usefulness, equipment should be able to perform *either or both* functions. The makers' contact-making wattmeter was designed for this purpose, but it does not exercise discrimination as to the time duration of this load. A second mechanism is necessary. Both motor driven and thermal types of time-delay relays, when used as this second mechanism in the past, prevented load from being shut down as result of momentary peaks, and also prevented chattering of relays and signals or too-frequent operation of switches when load hovered near limit, but both had disadvantages: With motor-driven type, delay was fixed once mechanism was adjusted and did not vary with character of load; and after device tripped, a temporary opening of energizing contacts (resulting from momentary dip in load) would cause mechanism to re-set and repeat its full time cycle. With thermal devices it was possible to have time delay inversely proportional to load, but these devices had comparatively narrow adjustment ranges, were difficult to pre-set for a desired time delay, and in some cases were affected by ambient temperature. With neither type was it possible to have equal delays accorded to rising and falling loads. (That is, when subjected to a decreasing load, the instrument should re-set at the same time rate at which it was originally released by an increasing load.) There is now announced a Time-delay Demand Relay which, used in conjunction with the makers' contact-making wattmeter, provides an adjustable time delay governed by nature of load and equal in both directions. The new device embodies two self-starting synchronous electric clock motors—one (A) continuously energized from supply line, the other (B) intermittently from "high" contact of contact-making wattmeter—arranged to revolve in opposite directions and, through a differential gearing and friction clutch, to drive a pointer-and-contact arm identical with that used in contact-making instrument. "A" drives pointer down-scale; while "B," operated from the wattmeter, drives it up-scale. Differential gearing is such that pointer has equal speeds when traveling either right or left. Hence, equal time delays in both directions. Friction clutch prevents overstress when either contact is reached. As long as load remains below predetermined value, upper contact on wattmeter remains open; only "A" is energized, and pointer is driver down-scale. Whenever load exceeds predetermined value, instrument contact closes, "B" is energized and pointer-and-contact arm driven up-scale. If contact on primary wattmeter is alternately made and broken by a varying load, time-delay demand mechanism will integrate this effect, moving pointer alternately up- and down-scale. Net result is to add up time during which load has exceeded limit for which contacting wattmeter is set, and to subtract time during which load has been less. Thus, if a uniformly low load has been maintained for hours and a sudden high load occurs, device will afford a maximum delay corresponding to point for which it is adjusted. If load has been hovering around critical point, the time delay will be correspondingly less because pointer and contacts will already be up part of scale. Instrument shown in diagram is so geared that time required for pointer to travel completely across scale is four minutes. Since upper contact arm is movable, maximum delay can be adjusted for any value up to 4 min., in infinitely small increments, with an accuracy of setting of ± 5 sec. As supplied where block intervals are 15 or 30 minutes, instrument has standard 12-min. time limit and ± 15 sec. accuracy. Scale and pointer are visible through window; functioning of instrument can also be observed without opening door.



Various combinations are possible because new device has an adjustable contact and associated contact-making wattmeter has both high and low adjustable contacts. Actual working load in k.w., critical load in k.w. and time delay in minutes are continuously visible on direct-reading scales. Since upper contact on the wattmeter can be used for controlling other circuits, alarm-sounding and switch-operation functions may be divided in various ways between the two instruments. One is to use contacts on wattmeter for operation alarm circuit, and contacts on the delay mechanism for circuit breaker control. With this arrangement, signal will operate whenever total load exceeds point at which instrument is set, but no other automatic operation will take place. This warns human operators that demand limit is being exceeded and that non-essential loads must be shut down promptly. If load is not sufficiently reduced within time for which delay device is set, delay mechanism will then accomplish load reduction automatically.

New instrument is not intended to check power company's block interval demand meter. It is housed in makers' standard contact-making instrument case, switchboard or wall type.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ZERO STOP: MAY ALSO BE USED AS RELAY RESETTING CONTACT.
DIFFERENTIAL GEARING.
INTERMITTENT RUNNING SYNCHRONOUS MOTOR, OPERATED FROM CONTACT CONTROL WATTMETER. DRIVES POINTER & MOVING CONTACT TOWARD RIGHT HAND END OF SCALE.
110 V. 60~ A.C.
UPPER CONTACT OF CONTACT CONTROL WATTMETER.
TO ALARM, RELAY OR CIRCUIT BREAKER
ADJUSTABLE STATIONARY CONTACT.
1 2 3 4
SERIAL NO MAXIMUM TIME DELAY-MINUTES PATENTED
FRICTION CLUTCH
CONTINUOUS RUNNING SYNCHRONOUS MOTOR, DRIVES POINTER & MOVING CONTACT TOWARD LEFT HAND END OF SCALE.
110 V. 60~ A.C.
B
A

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INSTRUMENTS BOOK SHELF

National Physical Laboratory Report for the Year 1933. His Majesty's Stationery office, London, 1934. Paper, 8 x 10½ inches, 264 pages. Price 13s.

The report covers the activities of the National Physical Laboratory during 1933. The reviewer will only make reference to those parts of the report pertaining to measurement.

In the physics department further work was carried out on the thermal and electrical conductivity of metals at high temperatures, high-temperature thermometry, X-ray analysis of the internal structure of metals, and the dosage of X-rays and gamma rays.

The electricity department carried on research on interelectrode capacitances of thermionic tubes, frequency standardization, absolute measurement of resistance, photometric measurements of gaseous discharge tubes, and glare.

The Metrology department carried out the decennial comparisons of the Imperial Standard Yard, and worked on a new wave-length comparator, as well as the stability of heat-treated hardened steel gages.

The engineering department developed a new form of fatigue testing machine. This machine permits materials to be tested under any combination of simultaneous cycles of torsion and flexure stresses.—RICHARD RIMBACH (1.2)-B-

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F. K. RICHTMYER, Editor

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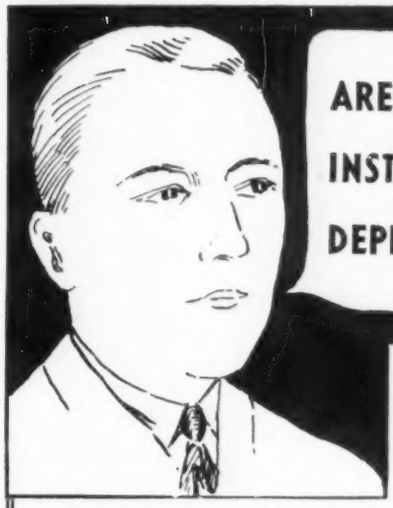

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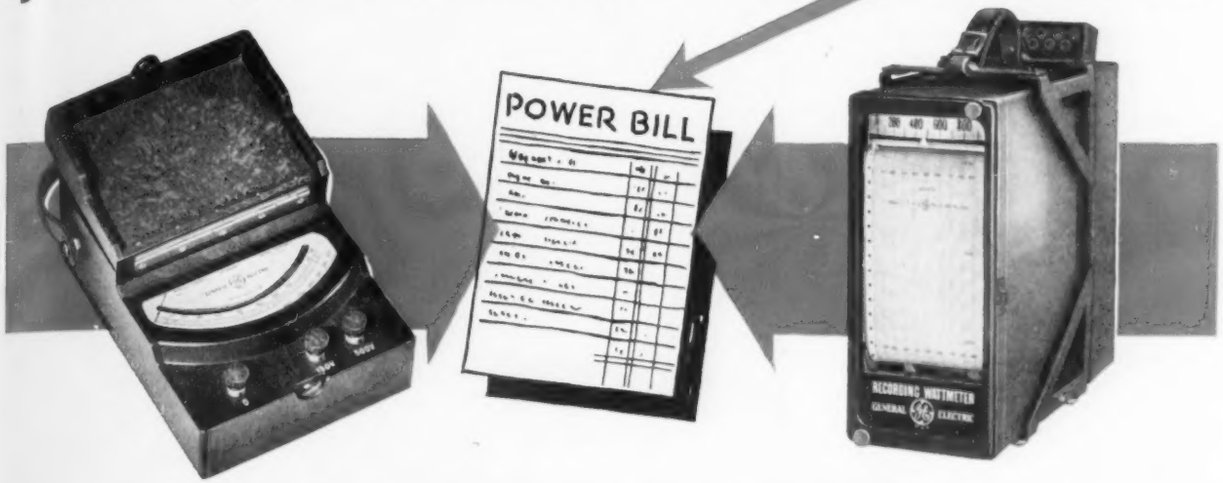

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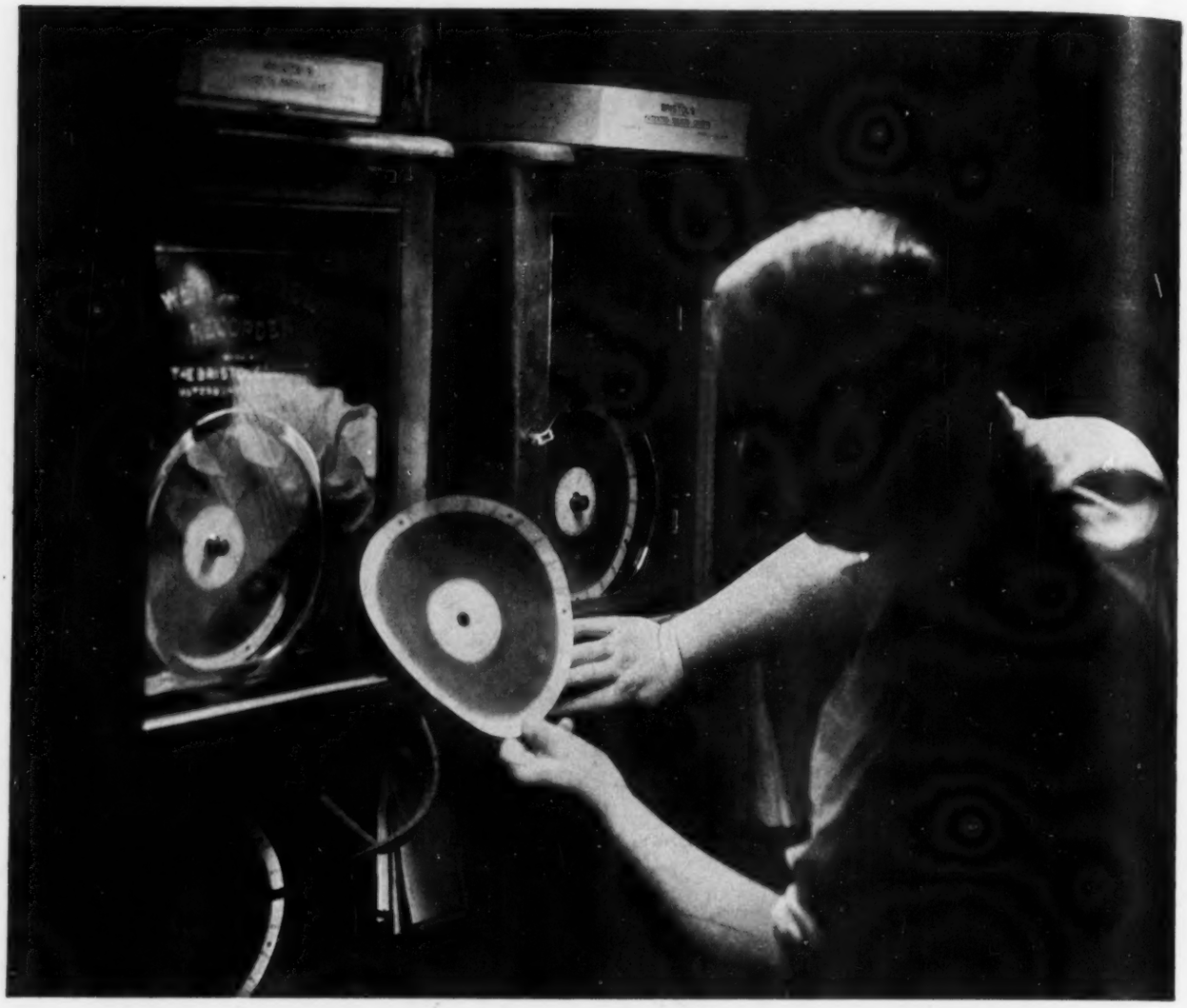

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